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The Copenhagen Classification System for Distal Humeral Fractures is useful to identify patients who may require treatment with hemi- or total elbow arthroplasty

Ali Al-Hamdani, MD[a,*], Jeppe V. Rasmussen, MD, PhD[a], Mustafa A. Al-Hamdani, MD[b], Anne Kathrine B. Sørensen, MD[a], Jacob Eschen, MD[c], Bo S. Olsen, MD, PhD[a]

[a]Department of Orthopaedic Surgery, Herlev and Gentofte Hospital, University of Copenhagen, Copenhagen, Denmark
[b]Department of Orthopaedic Surgery, Zealand University Hospital, Køge, Denmark
[c]Department of Orthopaedic Surgery, Privathospitalet Danmark, Copenhagen, Denmark

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Background: Classification systems are only useful if there is agreement among observers. The purpose of this study is to introduce a simple and clinically applicable classification system – The Copenhagen Classification System for Distal Humeral Fractures (CCDHF) and to compare the interobserver and intraobserver agreement for this classification with the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA), and the Sheffield classification systems. The primary objective of the new classification system is to distinguish fractures that may not be suitable for open reduction and internal fixation, necessitating treatment options such as elbow hemiarthroplasty or total elbow arthroplasty (TEA).

Methods: Five consultant elbow surgeons assessed a consecutive series of 105 sets X-rays of distal humeral fractures on 2 occasions with at least 10 weeks interval. All X-rays were classified according to AO/OTA, Sheffield, and the CCDHF systems. The CCDHF system has been developed collaboratively by a panel of five experienced elbow surgeons. Based on consensus, the surgeons identified specific fracture characteristics where elbow hemiarthroplasty or TEA might be needed.

Results: The mean interobserver agreement was fair for AO/OTA and moderate for Sheffield and the CCDHF. The mean intraobserver agreement was moderate for AO/OTA and substantial for Sheffield and the CCDHF. The observers were uncertain about the classification in 29% of the cases with the AO/OTA classification, 15% with the Sheffield classification, and 12% with CCDHF.

Conclusion: The CCDHF demonstrated validity and clinical applicability and can assist surgeons in identifying fractures that may require hemiarthroplasty or TEA treatment.

The purpose of classifying fractures is to assist the surgeon in selecting the most appropriate treatment, to inform patients about their individual prognosis and to serve research purposes. Classification systems are, however, only useful if there is agreement among observers.[8] The Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA) classification system classifies distal humeral fractures into three types depending on fracture character: extra-articular, intra-articular with or without the involvement of a single column, and intra-articular with involvement of both columns.[12] So, the fractures are classified into three types, nine groups, and 27 subgroups. This classification system is currently the most widely used. Over 50 years ago, Riseborough and Radin[18] introduced a classification system to classify intercondylar T-shaped fractures. The fractures were classified into four types depending on displacement, rotation, and comminution of the fragment. Jupiter and Mehne[9] developed a classification system in 1992 based on three main groups: intra-articular, extra-articular intracapsular, and extra-articular extracapsular. This classification took the anatomy of the distal humerus into consideration. In 2000, Wainwright et al[21] assessed interobserver and intraobserver variation of the previously mentioned classification systems. The authors concluded that the use of these classification systems and the widely used AO classification system was questionable.

Institutional review board approval was not required for this study.

*Corresponding author: Ali Al-Hamdani, MD, Gentofte Hospital, Gentofte Hospitalsvej 1, 2900, Hellerup, Denmark.
E-mail address: ali.kuthayer.khalil.al-hamdani@regionh.dk (A. Al-Hamdani).

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In 2006, Davies and Stanley[8] from Sheffield developed a clinically applicable classification system for distal humeral fractures. The fractures were classified into three main types; Type 1; extra-articular, Type 2; predominantly intra-articular, and Type 3; predominantly articular. They recommend Open Reduction and Internal Fixation (ORIF) without olecranon osteotomy for Type 1 and ORIF with olecranon osteotomy for Type 2 fractures. For type 3 fractures, ORIF with olecranon osteotomy is recommended for active and healthy patients, and total elbow arthroplasty (TEA) for elderly patients with low demand and with preexisting elbow osteoarthritis. They concluded that the classification was reliable and reproducible compared to the AO, the Riseborough and Radin, and the Mehne and Jupiter classification systems.

Since the introduction of the Sheffield classification, the treatment of multifragmentary intraarticular distal humeral fractures has evolved from ORIF towards the use of elbow arthroplasty and especially the use of elbow hemiarthroplasty (EHA).[2,6,13] Thus, previous studies have reported that EHA is a good and reliable treatment option for distal humeral fractures not amendable by ORIF.[2,6,13,15] The main advantage of EHA is preserving the ligament stability of the elbow joint through reattachment of the epicondyles and collateral ligaments to the prosthesis. This may help to minimize the potential for mechanical complications associated with TEA and reduce weight-bearing restrictions.[2] Thus, there is a need for a new and straightforward classification system that can differentiate fractures that may not be amenable to ORIF and indicate the potential need for treatment at a specialized tertiary center where EHA and TEA are available. Adult distal humeral fractures constitute a relatively small proportion, ranging from 2% to 5% of all fractures and accounting for approximately 30% of all elbow fractures.[3,19] Based on previous research findings, centers performing an average of 18 or more procedures annually can be considered as high-volume centers.[16] As a result, we propose that the management of these complex fractures should be centered in a select number of high-expertise centers.

The purpose of this study was to introduce a simple and clinically applicable classification system (Copenhagen Classification of Distal Humeral Fractures [CCDHF]) and to compare interobserver and intraobserver agreement for this classification system with the AO/OTA and Sheffield classification systems.

Materials and methods

Evaluation of the X-rays

Five experienced elbow surgeons (AA, JR, AS, JE, BO) independently assessed a consecutive series of 105 anteroposterior and lateral X-rays on two occasions at minimum ten-week intervals. Adult patients who were admitted to our emergency department in the period between 2011 and 2019 were included. X-rays with a single projection or those not specifically focusing on the elbow joint were excluded. Nonstandardized projections were not used as exclusion criteria, as the aim was to have a diverse set of X-ray images that represent real-world scenarios. The set of X-rays were collected and stored electronically by the first author (AA). Another author (MA), who was not an assessor, presented the anonymized imaging material to the assessors on two separate occasions with at least a ten-week interval between the two assessments. A new random order of the X-ray sets was used in the second evaluation. The assessors evaluated the X-ray

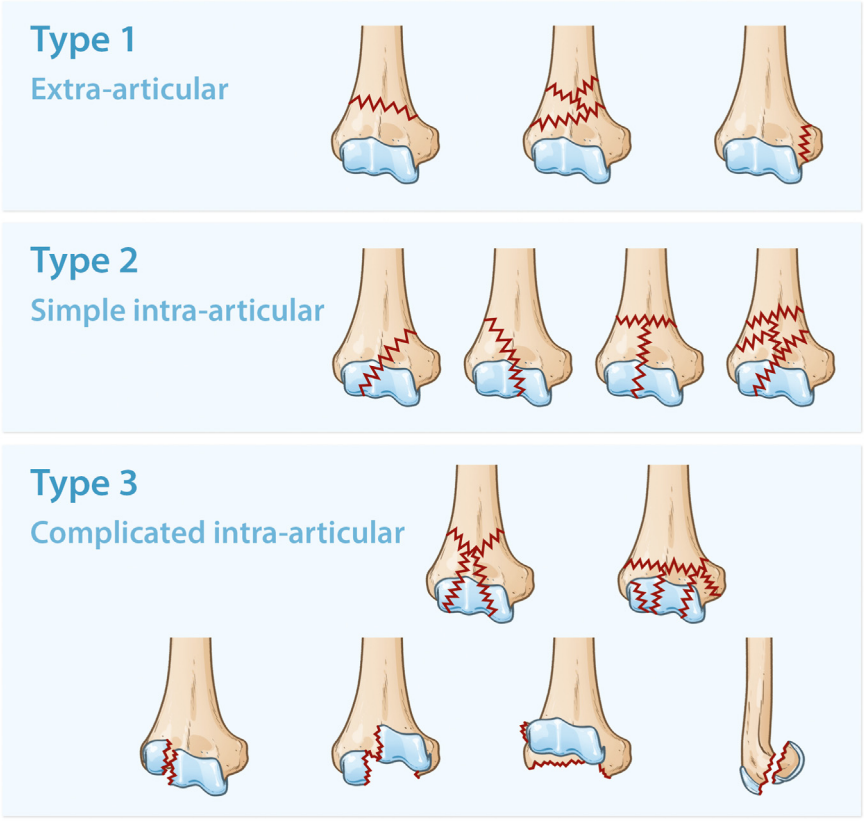

Figure 1 Copenhagen Classification system for distal humeral fractures (CCDHF).

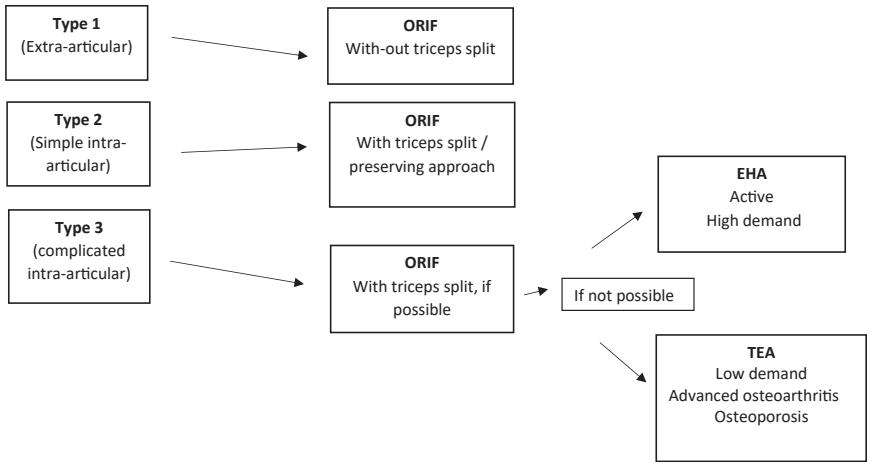

Figure 2 Treatment algorithm. *ORIF*, open reduction and internal fixation; *TEA*, total elbow arthroplasty; *EHA*, elbow hemiarthroplasty.

sets independently and were blinded to the patient's age, sex, comorbidities, and treatment. The assessors were asked to classify the fracture according to AO/OTA distal humeral fracture classification system (group and type), the Sheffield classification system for distal humeral fractures, and the CCDHF. During the assessment, the assessors were provided with relevant diagrams showing the fracture appearance in the three classification systems. They were also asked to report if they were uncertain about classifying each set of radiographs according to each classification system.

The new classification system

The new classification system, CCDHF, has been developed collaboratively by a panel of five consultant elbow surgeons (AA, JR, AS, JE, BO). Based on a consensus decision, the surgeons identified specific fracture characteristics where EHA or TEA may be needed. The CCDHF classifies fractures of the distal humerus into three main types: Type 1 fractures are extra-articular fractures identical to the AO/OTA type A and Sheffield type 1. Type 2 fractures are simple intra-articular fracture involving either a single column or bicolumnar with one fracture line running through the articular surface of the distal humerus, which is similar to the AO/OTA type B1, B2, and C2, and partially Sheffield type 2 fractures. Type 3 fractures are comminuted intra-articular fractures involving one or both columns and with a minimum of two fracture lines through the articular surface of the distal humerus, as well as shear fractures. This is like the AO/OTA type B3 and C3, Sheffield type 3, and partially Sheffield type 2 fractures (Fig. 1).

Table I
Interpretation of kappa-values according to the guidelines of Landis and Koch.[10]

Kappa statistic	Strength of agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost perfect

Clinical application

A treatment algorithm was suggested for this classification based on the results of previously published studies regarding the surgical treatment of distal humeral fractures (Fig. 2).[2,6,7,11,13,14,20] The suggested treatment algorithm reflects the current approach to managing these fractures in our department.

Statistical methods

We measured the mean kappa-values for interobserver and intraobserver agreement, and we used the guidelines of Landis and Koch[10] to evaluate our results, Table I.

Results

The mean interobserver agreement was fair for the AO/OTA classification (kappa 0.342 confidence interval [CI] 0.233-0.449) and moderate for the Sheffield classification (kappa 0.583 CI 0.455-0.710) and the CCDHF (kappa 0.506 CI 0.367-0.645) -Table II. The mean intraobserver agreement was moderate for the AO/OTA (kappa 0.584 CI 0.472-0.697) classification and substantial for the Sheffield (kappa 0.735 CI 0.617-0.853) and the CCDHF (kappa 0.707 CI 0.581-0.836) - Table III. The observers were uncertain about the classification in 29% of the cases with the AO classification, 15% with the Sheffield classification, and 12% of the cases with the CCDHF.

Table II
Mean kappa-values (k) and 95% Confidence Interval (95% CI)[17] for interobserver agreement.

	AO classification k (95% CI)	Sheffield classification k (95% CI)	CCDHF k (95% CI)
First round	0.331 (0.222-0.436)	0.504 (0.377-0.631)	0.508 (0.370-0.645)
Second round	0.352 (0.243-0.462)	0.661 (0.533-0.789)	0.505 (0.364-0.645)
Mean	0.342 (0.233-0.449)	0.583 (0.455-0.710)	0.506 (0.367-0.645)

CI; confidence interval; *AO*, Arbeitsgemeinschaft für Osteosynthesefragen; *CCDHF*, Copenhagen Classification System for Distal Humeral Fractures.

Table III
Mean kappa-values (k) and 95% Confidence Interval (95% CI)[17] for intraobserver agreement.

Observer	AO classification k (95% CI)	Sheffield classification k (95% CI)	CCDHF k (95% CI)
1	0.601 (0.481-0.721)	0.564 (0.439-0.689)	0.672 (0.527-0.827)
2	0.796 (0.688-0.904)	0.862 (0.754-0.970)	0.842 (0.722-0.962)
3	0.358 (0.242-0.474)	0.765 (0.655-0.875)	0.679 (0.555-0.803)
4	0.663 (0.557-0.769)	0.825 (0.727-0.923)	0.640 (0.582-0.826)
5	0.504 (0.392-0.616)	0.658 (0.509-0.807)	0.640 (0.518-0.762)
Mean	0.584 (0.472-0.697)	0.735 (0.617-0.853)	0.707 (0.581-0.836)

CI; confidence interval; *AO*, Arbeitsgemeinschaft für Osteosynthesefragen; *CCDHF*, Copenhagen Classification System for Distal Humeral Fractures.

Figure 3 (**A**) 77-year old fit man with CCDHF type 2 fracture and without osteoarthritis. Treated with ORIF. (**B**) 74-year-old lady with CCDHF type 3 fracture and rheumatoid arthritis. Treated with TEA. (**C**) 76-year old fit lady without osteoarthritis treated with EHA for CCDHF type 3 fracture not amenable for ORIF. (**D**) 22-year old active and fit lady treated with screw fixation of CCDHF type 3 fracture. *ORIF*, open reduction and internal fixation; *TEA*, total elbow arthroplasty; *EHA*, elbow hemiarthroplasty; *CCDHF*, Copenhagen Classification System for Distal Humeral Fractures.

Discussion

The mean interobserver agreement among consultant elbow surgeons for AO/OTA classification was fair, and the mean intraobserver agreement was moderate. The mean interobserver agreement for the Sheffield Classification and the CCDHF was moderate, and the intraobserver agreement was substantial (Tables II and III). It's important to underline that the X-rays used in this study were taken in the emergency department, where the fractures might not have been optimally exposed. The consequences are lower observer agreements, and it can be hypothesized that the use of CT scans could offer benefits in the classification of distal humeral fractures.

The purpose of implementing the CCDHF was to introduce a clinically applicable classification system that can be used to identify patients who require treatment in a tertiary center, where EHA and TEA are available. The CCDHF can be used with the suggested treatment algorithm (Fig. 2), which represents the current approach to managing distal humeral fractures in our department. The algorithm is based on the results of previously published studies regarding the surgical treatment of distal humeral fractures including the growing evidence supporting the use of EHA,[1-4,6,7,11,13-15,19,20] taking in consideration that the Sheffield classification was introduced at a time when EHA was not commonly used. We suggest ORIF without triceps split for CCDHF type 1 fractures, and ORIF with triceps split or triceps preserving approach, depending on fracture complexity and the preference of the surgeon, for CCDHF type 2 fractures. We also recommend ORIF with triceps split, if possible, for CCDHF type 3 fractures. Otherwise, TEA should be chosen for elderly patients with osteoporotic bones or preexisting significant osteoarthritis and EHA for active middle-aged and elderly patients without significant osteoarthritis. We do accept suboptimal ORIF in younger patients, and EHA can only be an option in extreme cases (Fig. 3).

The CCDHF and the Sheffield classification system demonstrated comparable interobserver and intraobserver agreement. However, we have concerns regarding the recommendation to treat all Sheffield type 2 fractures with ORIF,[8] especially the comminuted intra-articular type equivalent to AO/OTA 13 C3 fractures. We believe that some of these fractures may require treatment with elbow arthroplasty. Furthermore, not all Sheffield type 3 fractures in fit and active patients can be treated with ORIF. Consequently, the CCDHF might be more useful to identify fractures that might require treatment with EHA or TEA.

In Sheffield and Oxford studies[8,21] the same 33 X-ray sets were used, and the order of presentation of the X-ray sets was not rerandomized on the second round. The X-rays were assessed by three trauma registrars, three orthopedic trauma consultants, and three musculoskeletal consultant radiologists. The two studies reported moderate interobserver and intraobserver agreement for AO/OTA classification system, whereas our study reported a fair interobserver agreement but a moderate intraobserver agreement. The Sheffield study[8] reported a substantial agreement with their own classification system (kappa 0.664), whereas we reported moderate agreement with Sheffield and with the CCDHF (kappa 0.583-0.506, respectively). The reason for the different findings could be related to a higher level of consensus among the consultant musculoskeletal radiologists involved in the Sheffield and Oxford studies, a larger sample size in our study, which included 105 X-ray sets, and, especially, the rerandomization of the presentation order on the second occasion.

No elbow surgeon participated in the classification process in the Sheffield study, unlike the current study where the assessment was carried out by consultant elbow surgeons with broad expertise in managing these fractures, including treatment with hemi and total arthroplasty. The expertise of the assessors in treating these fractures may increase the clinical applicability of the CCDHF.

Bernstein et al in their study from 1997 titled “Classification of fracture classifications”[5] developed a grading system to evaluate the classification of fractures based on clinical applicability. They assessed the degree to which the requirements of treatment could be based on the classification. They assumed that the best classification system should establish a direct correlation between the type of fracture and the treatment option (Fig. 4).

The AO/OTA[12] classification cannot be classified as Grade A or Grade B status due to its complexity and many subgroups. According to Sheffield study,[8] their classification system can attain Grade B status, and it may achieve Grade A if only young and active patients are included, but we respectfully disagree. The Sheffield classification system cannot attain Grade A or Grade B, as not all Sheffield Type 2 and Type 3 fractures can be treated with ORIF. The CCDHF achieve Grade B1 status. It establishes a clear one-to-one relationship for type 1 and type 2 fractures, but type 3 fractures can be treated with either ORIF or EHA/TEA.

The limitation of this study is the absence of involvement of registrars or traumatologists in the assessment process. Furthermore, the assessment exclusively relied on plain X-rays and not computed tomography (CT) scans, which are now routinely used in many centers worldwide. The use of CT scans might improve the observer agreement, and we suggest that CT scans are considered when future studies dealing with observer agreement for distal humeral fractures are being planned.

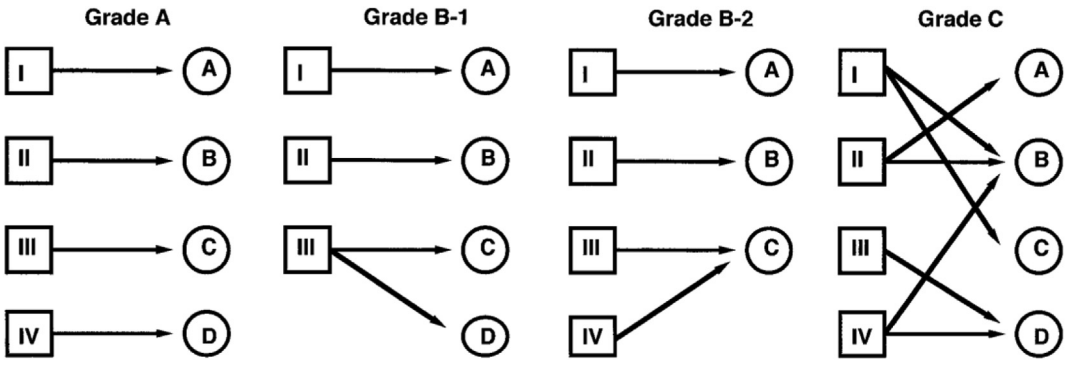

Figure 4 The relationships between classification categories and treatment options.

Conclusion

The CCDHF demonstrated validity and clinical applicability in classifying distal humeral fractures, showing a moderate level of agreement among observers. The CCDHF can be used to assist surgeons in identifying fractures requiring treatment in a tertiary center, where hemiarthroplasty and TEA are available.

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