

Reliability and Reproducibility of the OTA/AO Classification for Humeral Shaft Fractures

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Ethical approval

The study was exempted by the Medical Research Ethics Committee Erasmus MC (No. MEC-2014-107).

ABSTRACT

Objectives: This study aimed to determine inter-observer reliability and intra-observer reproducibility of the OTA/AO classification for humeral shaft fractures, and to evaluate differences between fracture types, fracture groups, and surgical specializations.

Methods: 30 observers (25 orthopedic trauma surgeons and five general orthopedic surgeons) independently classified 90 humeral shaft fractures according to the OTA/AO classification. Patients of 16 years and older were included. Periprosthetic, recurrent, and pathological fractures were excluded. Radiographs were provided in random order, and observers were blinded to clinical information. To determine intra-observer agreement, radiographs were reviewed again after two months in a different random order. Agreement was assessed using kappa statistics.

Results: Inter-observer agreement for the three fracture types was moderate ($\kappa=0.60$; 0.59-0.61). It was substantial for type A ($\kappa=0.77$; 0.70-0.84), and moderate for type B ($\kappa=0.52$; 0.46-0.58) and type C fractures ($\kappa=0.46$; 0.42-0.50). Inter-observer agreement for the nine fracture groups was moderate ($\kappa=0.48$; 95% CI 0.48-0.48). Orthopedic trauma surgeons had better overall agreement for fracture types, and general orthopedic surgeons had better overall agreement for fracture groups. Observers classified 64% of fractures identically in both rounds. Intra-observer agreement was substantial for the three types ($\kappa=0.80$; 0.77-0.81) and nine groups ($\kappa=0.80$; 0.77-0.82). Intra-observer agreement showed no differences between surgical disciplines.

Conclusions: The OTA/AO classification for humeral shaft fractures has a moderate inter-observer and substantial intra-observer agreement for fracture types and groups.

INTRODUCTION

A fracture classification system should not only provide a reliable and reproducible means of communication between physicians, but also provide for repeated viewings of the same material.¹ Ideally it should have a prognostic value for the outcome of patients, assist in managing fractures, and assist documentation and research.² Humeral shaft fractures are most widely classified using the OTA/AO classification system.^{1, 3}

Despite its widespread use, the OTA/AO classification has not been validated for humeral shaft fractures, including the complete range of fracture types and groups. The primary aim of this study was therefore to determine the inter-observer reliability and intra-observer reproducibility of the OTA/AO classification for humeral shaft fractures. The secondary aims were to evaluate if reliability and reproducibility differed between the three different fracture types or the nine fracture groups, and to assess if agreement was dependent on surgical specialization or time spent on classifying the radiographs.

METHODS

Classification

In the OTA/AO classification, number 1 stands for the humerus and number 2 for the diaphyseal segment. As shown in Figure 1, three types of fractures are defined and coded with letters: type A consists of simple fractures, type B of wedge-type fractures, and type C of complex fractures. Each of these three types can be further subdivided into groups 1, 2, or 3. Overall, the OTA/AO classification system for humeral shaft fractures has nine groups (12-A1/2/3, 12-B1/2/3, 12-C1/2/3).²

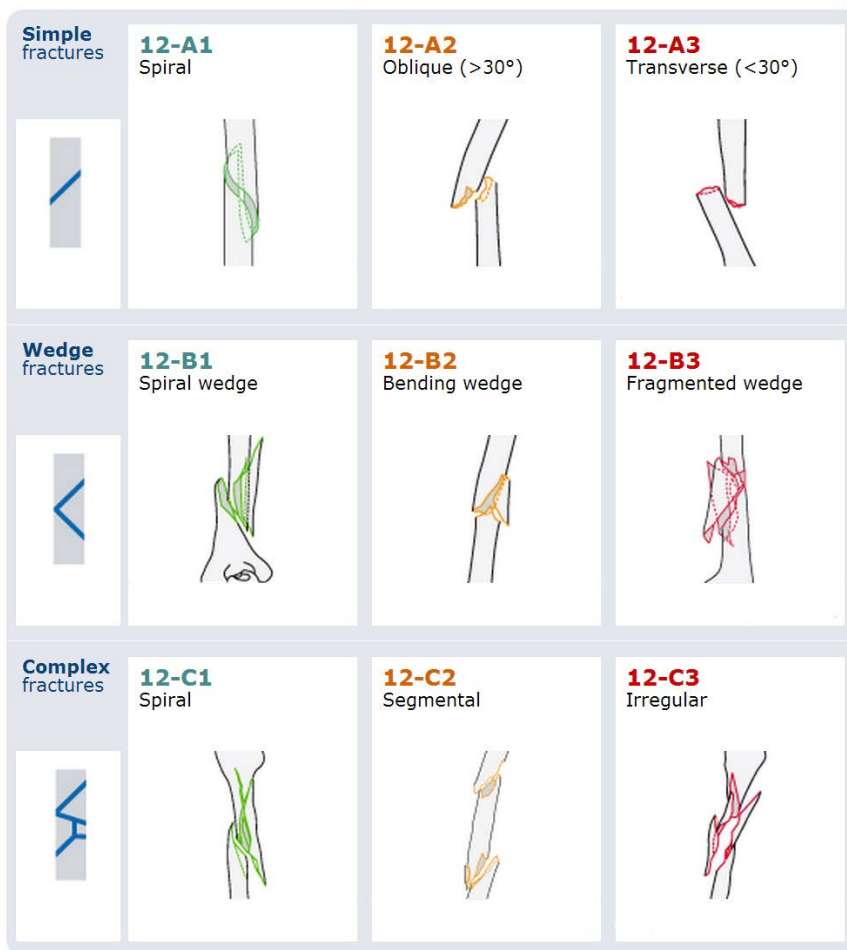


Figure 1. OTA/AO classification for humeral shaft fractures^{1,3}

Study subjects

Patients were selected from the hospital records and from the radiology system PACS (Picture Archiving and Communication System) of three hospitals. Eligible patients had already been identified from hospital databases as part of another study.⁴ All patients aged 16 years or older treated for a humeral shaft fracture in one of three hospitals were included in this study. The humeral shaft was defined as the area between the surgical neck and the area immediately above the supracondylar ridge. Radiographs had to include initial (i.e., before treatment) anterior-posterior or lateral images. Patients with periprosthetic, recurrent, or pathological fractures were excluded. Patients with fractures extending outside the predefined shaft area were excluded as well. A total of 90 patients representing the full spectrum of humeral shaft fractures were selected by the clinical investigator (KCM). The investigator was adequately trained, had sufficient experience to select the radiographs of humeral shaft fractures and was not involved as observer. The sample size of 90 patients allowed for all groups to be represented with ten subjects. The first ten subjects per group were included. In order to reflect routine day-to-day practice the quality of the images was not used as an exclusion criterion. The radiographs that were accepted for clinical decision making were also considered adequate for this classification study. All radiographs available (two or three for 85 patients and one for the other five) were used. Radiographs had no identifying information. Following randomization using a web-based list randomizer (www.random.org), they were imported into an open-source Digital Imaging and Communications in Medicine (DICOM) compliant viewer (RadiAnt DICOM Viewer 1.9.14, Medixant, Poznan, Poland). This viewer provided all necessary tools for adequate viewing (e.g., fluid zooming and panning, brightness and contrast adjustments, and angle measurements). The same workstation and DICOM viewer were used for all observations in order to guarantee identical viewing conditions.

Observers

Thirty-seven consultant upper extremity (orthopedic) trauma surgeons experienced in the treatment of humeral fractures were invited to act as observer. All surgeons act as site principal investigator in a multicenter clinical study comparing the operative and non-operative treatment of humeral shaft fractures (HUMMER study).⁵ Years of independent practice and whether the OTA/AO classification is used in daily practice were noted for each observer.

Study procedure

Each observer independently classified 90 humeral shaft fractures according to the classification system. All radiographs were provided in random order, and the observers were given as much time as needed for accurate assessment. Observers were blinded to clinical information and were not allowed to discuss their observations with other investigators. All observers were familiar with the OTA/AO classification system used in this study. In order to ensure unambiguous application of the fracture classification system, an overview of the classification system was available to the surgeons during the classification (Figure 1). The amount of time needed to classify all radiographs was recorded.

In order to determine the intra-observer agreement, all radiographs were reviewed a second time at least two months after the first review. On the second occasion, images were provided in a different random order. Inter-observer reliability is the degree of agreement when two or more independent observers classify the same fracture. Intra-observer reproducibility is agreement when one observer classifies the same fracture more than once.

Statistical analysis

Normality of continuous data was judged from frequency histograms and Q-Q plots, homogeneity of variances was tested using the Levene's test. Data were analyzed using Kappa statistics, as described by Cohen.⁶ The kappa coefficient represents the agreement between two sets of observations compared with the likelihood of agreement based on chance alone. The kappa coefficient ranges from 1 (perfect agreement) to <0 (systematic disagreement, or no more agreement than would be expected by chance alone). The kappa value for inter-observer agreement was calculated for each possible pair of observers before calculating the mean kappa value.⁷ Interpretation of the values were carried out according to the guidelines of Landis and Koch, which suggest that values <0 represent poor reliability; 0.00-0.20 slight agreement; 0.21-0.40 fair agreement; 0.41-0.60 moderate agreement; 0.61-0.80 substantial agreement; and 0.81-1.00 almost perfect agreement.⁸ The kappa value for intra-observer agreement were calculated for each of the individual observers before calculation the mean kappa value. The kappa values were classified according to Landis and Koch as described in the previous section.

Kappa values for both inter- and intra-observer agreement were assessed for the nine groups (12-A1/2/3, 12-B1/2/3, 12-C1/2/3), as well as for the three types (A, B and C) in order to judge if kappa values differ between fractures. Statistical significance of differences in the kappa values across these groups and types were tested with a one-way Analysis of Variance (ANOVA). Statistical significance of differences between orthopedic trauma and general orthopedic surgeons and time spent on the classification of all radiographs were tested with the a Student's t-test. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21 or higher (SPSS, Chicago, Ill., USA).

RESULTS

Twenty-five of the observers were orthopedic trauma surgeons and five were general orthopedic surgeons. Of the observers 11 worked ten years or less in an independent practice and 19 had more than ten years of experience in an independent practice.

As shown in Table 1, the inter-observer reliability was moderate for the three fracture types ($\kappa=0.60$; 95% CI 0.59-0.61). It was substantial for type A fractures ($\kappa=0.77$; 95% CI 0.70-0.84), and moderate for type B ($\kappa=0.52$; 95% CI 0.46-0.58) and type C fractures ($\kappa=0.46$; 95% CI 0.42-0.50).

The inter-observer agreement for the nine groups was moderate ($\kappa=0.48$; 95% CI 0.48-0.48). It was highest for 12-A3 fractures ($\kappa=0.68$; 95% CI 0.64-0.71) and 12-C3 fractures ($\kappa=0.63$; 95% CI 0.60-0.66) and lowest for 12-C1 fractures ($\kappa=0.24$; 95% CI 0.21-0.27). The overall inter-observer agreement for three fracture types and nine groups both showed statistical significance differences between orthopedic trauma and general orthopedic surgeons. Orthopedic trauma surgeons had better overall agreement for fracture types ($\kappa=0.60$; 95% CI 0.61-0.59 and $\kappa=0.58$; 95% CI 0.53-0.62, respectively). For overall inter-observer agreement for the nine groups it was the other way around and general orthopedic surgeons had better overall agreement ($\kappa=0.47$; 95% CI 0.47-0.48 and $\kappa=0.51$; 95% CI 0.50-0.53, respectively).

No differences were found between surgical specialization and agreement of specific fracture types or groups, except for the 12-B1 fracture group. Orthopedic trauma surgeons had a lower inter-observer agreement for that specific group than general orthopedic surgeons ($\kappa=0.33$; 95% CI 0.28-0.37 and $\kappa=0.47$; 95% CI 0.31-0.62, respectively).

The intra-observer reproducibility was substantial as shown in Table 2 ($\kappa=0.80$; 95% CI 0.77-0.81) for the three types, as well as for the nine groups ($\kappa=0.80$; 95% CI 0.77-0.82). Observers classified 64% (95% CI 62-67%) of the fractures identically in both rounds. Intra-

observer agreement for types, groups or the percentage of identically classified fractures in both rounds did not differ between surgical specializations.

Both the inter- and intra-observer agreement were not significantly associated with the time spent on the classification of all radiographs.

Table 3 shows an overview of the number of dominant classifications of the 90 fractures classified. In addition, it shows the mostly chosen alternative per fracture type and group.

When the 12-A fracture type was the dominant classification, 12-B was the mostly chosen alternative (61% of classifications). For type 12-B, the mostly chosen alternative was type 12-C (66%). The type 12-B classification was mostly chosen as alternative (91%) when the type 12-C classification was dominant. For the type 12-A1 (simple spiral fracture), the 12-B1 (spiral wedge fracture) was the mostly chosen alternative. The 12-A2 and 12-A3 groups (oblique and transverse fractures, respectively), were both chosen mostly as alternative when these were the dominant classification. For 12-B1 and 12-C1 groups (spiral wedge and complex spiral fractures, respectively) and for 12-B2 and 12-B3 groups (bending wedge and fragmented wedge fractures, respectively) this was also the case. When the 12-C2 segmental group was dominant, the 12-A3 transverse group was chosen mostly as alternative.

Figure 2 shows an example of a fracture with perfect agreement. This fracture was classified in the 12-A2 group by all observers in both rounds. This was also the only fracture with perfect agreement in the entire study. An example of poor agreement is shown in Figure 3.

This fracture was classified in six different groups.



Figure 2. Example of a fracture with perfect agreement

Classified as 12-A3 by all observers in both rounds.



Figure 3. Example of a fracture with poor agreement

Classified into six different groups.

DISCUSSION

The main purpose of the current study was to determine whether the OTA/AO classification is a reliable and reproducible system for the classification of humeral shaft fractures. The inter-observer reliability was moderate and the intra-observer reproducibility was substantial. Although the usability of the OTA/AO classification has previously been questioned, it remains the most widely used classification system in the research of humeral shaft fractures.⁹

The validity of the classification has also been studied in various bone segments, but specific results of the classifications used for humeral shaft fractures are scarce.¹⁰⁻¹⁶ Johnstone et al. concluded in 1993 that the classification system for long bone fractures demonstrated a significant inter-observer variation, but no humeral shaft fractures were included in that study.¹⁷ In the same year, Newey et al. concluded that the classification system was only useful for audit options, but again no humeral shaft fractures were included.¹⁸ Meling et al. reported a moderate inter-observer agreement for the OTA/AO classification for long bone fractures ($\kappa=0.67$ (95% CI: 0.62-0.72)).¹⁹ A study comparing the OTA/AO classification for long bone fractures with a newly proposed classification, including 40 humeral shaft fractures classified by six observers, reported a fair inter-observer agreement ($\kappa=0.30$) and also a fair intra-observer agreement ($\kappa=0.38$) for the OTA/AO classification.²⁰ That classification system, describing fractures by location (proximal, middle, distal, or in combinations when the fracture is located in multiple zones) and morphology (simple [transverse, oblique or spiral], intermediate and complex), had a good inter-observer ($\kappa=0.66$) as well as a moderate intra-observer ($\kappa=0.56$) agreement.

As shown in Table 3, observers did not agree on specific fracture patterns. When most observers classified a fracture as a simple spiral fracture (12-A1), the remaining observers classified it as a spiral wedge (12-B1). When most observers classified a fracture as a spiral

wedge the remaining observers chose the complex spiral fracture (12-C1). Apparently, the fracture lines discriminating these fracture types were easily missed (or thought to be seen). Also, the angle of the fracture seemed difficult to determine. The angle separating the oblique (12-A2) and transverse (12-A3) fracture groups of 30 degrees seemed to cause observers to disagree. For future classifications, specific attention should be paid to these items.

CONCLUSION

The OTA/AO classification system for humeral shaft fractures has a moderate inter-observer agreement for the fracture types and fracture groups. Apart from a substantial agreement for type A fractures the agreement for the other fracture types was moderate. Agreement for specific fracture groups ranged from fair to substantial. The intra-observer agreement was substantial for the fracture types and groups, with 64% fractures classified identically in both rounds. Specific attention should be paid to discriminating A1 from B1, B1 from C1, and A2 from A3 as fracture lines or angles discriminating these two were often misinterpreted.

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