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Classification of proximal humeral fractures based on a pathomorphologic analysis

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Background: The purpose of this study was to analyze the pathomorphology of proximal humeral fractures to determine relevant and reliable parameters for fracture classification.
Methods: A total of 100 consecutive acute proximal humeral fractures in adult patients were analyzed by 2 non-independent observers from a single shoulder department using a standardized protocol based on biplane radiographs and 3-dimensional computed tomography scans. A fracture classification system based on the most reliable key features of the pathomorphologic analysis was created, and its reliability was tested by 6 independent shoulder experts analyzing another 100 consecutive proximal humeral fractures.
Results: The head position in relation to the shaft (varus, valgus, sagittal deformity) and the presence of tuberosity fractures showed a higher interobserver reliability ($\kappa > 0.8$) than measurements for medial hinge, shaft, and tuberosity displacement, metaphyseal extension, fracture impaction, as well as head-split component identification ($\kappa < 0.7$). These findings were used to classify nondisplaced proximal humeral fractures as type 1, fractures with normal coronal head position but sagittal deformity as type 2, valgus fractures as type 3, varus fractures as type 4, and fracture dislocations as type 5. The fracture type was further combined with the fractured main fragments (G for greater tuberosity, L for lesser). Interobserver and intraobserver reliability analysis for the fracture classification revealed a κ value (95% confidence interval) of 0.700 (0.631-0.767) and 0.917 (0.879-0.943), respectively.
Conclusion: The new classification system with emphasis on the qualitative aspects of proximal humeral fractures showed high reliability when based on a standardized imaging protocol including computed tomography scans.

The local Ethical Committee of Salzburg, Austria, approved this study (415-EP/73/5322015).

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Considerable controversy surrounds the treatment of proximal humeral fractures, particularly in elderly patients. Treatment options include nonoperative management, minimally invasive pinning techniques, locked plating, intramedullary nailing, hemiarthroplasty, and even reverse arthroplasty.[2,6,9,14,16,17,20] Several factors may be responsible for the existing controversy. One of the major issues is the analysis of fracture patterns, which often leaves room for interpretation.[18] Current classification systems are mainly based on the concept of fragment quantification and fracture localization.[4,12,13] Widely accepted qualitative concepts of proximal humeral fracture patterns, such as varus and valgus malposition of the head fragment,[15] metaphyseal extension, or displacement of the medial hinge,[4] have yet to be included in a fracture classification system. Varus and valgus malposition of the head fragment are associated with a different pattern of periosteal damage,[16] different primary stability,[5] different ways of fracture reduction,[11] and different functional outcome,[19,22] but metaphyseal extension and medial hinge displacement have been described as key prognostic factors for humeral head vascularity.[4]

Other than anatomical or clinical relevance, a fracture classification should offer little room for misinterpretation to be a reliable tool for clinical application or research. Because most of the current fracture classification systems are based on plain radiographs, the interobserver reliability is low.[21] An important factor in improving the reliability of fracture classification is the availability of a standardized, reproducible, high-quality imaging technique.

The purpose of the present study was to perform a qualitative analysis of the pathomorphology of proximal humeral fractures in a large consecutive case series based on a standardized radiologic evaluation protocol, including biplane radiographs and computed tomography (CT) scans with 3-dimensional (3D) reconstruction. A further goal was to create a new fracture classification system on the basis of the pathomorphologic analysis and to have its reliability tested by independent observers.

Materials and methods

The study used a standardized protocol to include 200 consecutive acute proximal humeral fractures in adults (70% women) in an urban level I trauma center. Excluded were patients younger than 18 years, others with delayed hospital admission (≥10 days after the injury), isolated tuberosity fractures, and pathologic fractures. The patients were an average age of 68.8 years (range, 20-94 years), with 106 patients older than 70 years at the time of injury. The right shoulder was involved in 50.5% of patients.

All patients underwent biplane radiography, including true anteroposterior and trans-scapular views, as well as CT imaging. CT images were obtained at the first author's institution using a 64-slice Somatom Sensation 64 CT scanner (Siemens, Erlangen, Germany) with a slice thickness of 0.6 mm. Axial, oblique coronal, and oblique sagittal images adapted to the plane of the shoulder were generated, and 3D reconstructions were obtained for all patients.

Pathomorphologic analysis

The image sets of the first 100 patients were analyzed by 2 shoulder surgeons (H.R. and P.M.) from a single department based on a structured questionnaire, which allowed them to describe the fracture morphology of the different cases with yes/no answers (Table I). The responses from the 2 observers were pooled, and the pathomorphology of the fractures was identified according to the recorded responses. In the case of nonconcordance of the fracture interpretation of the 2 observers, the fracture was reanalyzed and discussed. If agreement was found, the initial rating was changed accordingly, and if the raters continued to disagree, the initial ratings remained the same.

The following definitions were applied in the pathomorphologic analysis: The threshold value for coronal and sagittal head fragment malposition was set at 20°.[5,19,22] A tuberosity was considered to be displaced if at least 5 mm of displacement was measured.[1] Shaft displacement was defined as displacement by at least one-third of the shaft diameter in any direction. A proximal humeral fracture was considered to be a head-split type fracture if at least 20% of the head area in the transverse plane with the largest head diameter was affected.[10] The critical metaphyseal head extension from the anatomical neck was defined as 8 mm according to Hertel et al.[4] Furthermore, displacement of the fractured medial calcar by more than 2 mm was considered significant and was named hinge displacement, also according to Hertel et al.[4]

Fracture classification system evaluation

After the pathomorphologic analysis of the first 100 fractures was completed, a classification system was created based on the observed key distinctive fracture parameters and on the interobserver reliability of single criteria. Only parameters with high reliability ($\kappa > 0.81$ according to Landis and Koch[7]) were used in the fracture classification system. The positional relationship between the head and shaft fragment was determined to be the main classification criterion. Nondisplaced fractures were classified as type 1, fractures with normal coronal head position but sagittal