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Involvement of the lesser sigmoid notch in elbow fracture dislocations

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Background: This study addressed the primary null hypothesis that there is no difference in the articular surface area of the lesser sigmoid notch involved among Mayo classes. Secondarily, we analyzed the fracture line location and the pattern of lesser sigmoid notch articular surface involvement among Mayo classes.
Methods: Using quantitative 3-dimensional computed tomography, we reconstructed and analyzed fractures involving the lesser sigmoid notch articular surface in 52 patients. Further, we assessed the surface area involved in the fracture, the number of fracture fragments, and the location and direction of the fracture lines. Coronoid fractures were classified according to Mayo types.
Results: There was no significant difference between Mayo types 1 and 2 in any characteristic of the involvement of the lesser sigmoid notch articular surface, whereas Mayo type 3 was significantly different from both Mayo types 1 and 2 in the area involved in the fracture (42% in Mayo type 3 vs. 9% in Mayo types 1 and 2), the number of articular fragments (>3 fragments in type 3 vs. 2 fragments in types 1 and 2), and the direction of fracture line (both horizontal and vertical lines in type 3 vs. only horizontal line in types 1 and 2).
Conclusion: Mayo type III results in a more complex fracture, which might need to be addressed directly or indirectly during open reduction with internal fixation of olecranon fracture dislocations because changes in the geometry of lesser sigmoid notch may affect the radioulnar joint if it remains incongruent.
Level of evidence: Basic Science Study; Validation of Outcomes Instruments/Classification Systems

Keywords: Mayo; lesser sigmoid notch; coronoid; Q3DCT; elbow fracture; Monteggia; terrible triad; varus posteromedial instability

We have a limited understanding of how proximal ulnar fractures affect the lesser sigmoid notch. The lesser sigmoid notch articulates with the radial head[2,3] and also provides a landmark for positioning the radial head prosthesis after elbow fracture dislocations.[11] It is clear that some coronoid fractures enter the proximal radioulnar joint, but the fracture patterns of the lesser sigmoid notch are not well described. The Regan-Morrey and Mayo classifications of coronoid fractures primarily focus on the articular fracture pattern of the

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trochlear notch but do not consider lesser sigmoid notch involvement. The Regan-Morrey classification was based on the size of the fragment on a lateral radiograph. As computed tomography (CT) scans improved the understanding of coronoid fracture patterns, O'Driscoll introduced the Mayo classification based on shapes of coronoid fractures that are associated with specific patterns of injury.[5]

Quantitative (Q) 3-dimensional (3D) computed tomography (CT; Q3DCT) facilitates study of the morphology and articular fracture pattern of fractures.[4,6] In this study, we used Q3DCT to analyze lesser sigmoid articular involvement to address the primary null hypotheses that there is no difference in the articular surface area of the lesser sigmoid notch involved among Mayo classes. Secondarily, we hypothesized that there is no difference in the fracture line location and pattern of articular surface involvement among the Mayo classes.

Table I Demographics

Variables	Patients (n = 52)
Age, mean (SD), years	45 (14)
Sex, No. (%)	
Men	37 (71)
Women	15 (29)
Side of injury, No. (%)	
Right	19 (36)
Left	33 (64)
Treatment, No. (%)	
Surgical	43 (83)
Nonsurgical	9 (17)
Mayo classification, No. (%)	
Type 1	28 (54)
Type 2	8 (15)
Type 3	16 (31)
Injury patterns, No. (%)	
Terrible triad fracture-dislocation	27 (52)
Varus posteromedial rotational instability pattern	6 (12)
Olecranon fracture-dislocation	
Anterior olecranon fracture-dislocation	1 (2.0)
Posterior olecranon fracture-dislocation	11 (21)
Olecranon fracture with varus posteromedial instability	2 (4.0)
Posterior Monteggia injury associated with terrible triad fracture-dislocation	5 (9.0)

SD, standard deviation.

Methods

Patients

We searched the billing database of two level 1 trauma hospitals from July 2001 to January 2014 with International Classification of Diseases, 9th Revision, Clinical Modification codes 813.0× and 813.1× for closed and open elbow fractures, respectively, and Current Procedural Terminology (American Medical Association, Chicago, IL, USA) codes 24,586-24,685, which include radial and ulnar fractures, Monteggia type fractures, and elbow dislocations. We found 207 patients with coronoid fractures, of which 55 involved the lesser sigmoid notch in patients that were at least 18 years old and had a fracture completely visualized by CT with a slice thickness of 0.625 to 1.25 mm. Three patients were excluded because of low-quality CT images. The remaining 52 patients were analyzed. The most common pattern of traumatic elbow instability was the terrible triad (TT), and the second most common was posterior olecranon fracture-dislocation (Table I).

Quantitative 3DCT

The original CT scans of eligible subjects were obtained as Digital Imaging and Communications in Medicine (National Electrical Manufacturers Association, Rosslyn, VA, USA) files through the picture archiving communications system at each hospital and uploaded into 3D Slicer (Boston, MA, USA), a software program used to display and analyze medical images. The 3D Slicer tools PaintEffect and Threshold Paint were used to manually mark the proximal ulna, including fracture fragments, in transverse, sagittal, and oblique images. A voxel range of 225.00 to 1760.00 Hounsfield Units was used to identify bony structures.

Subsequently, 3D polygon mesh reconstructions were created (Fig. 1) and uploaded into Rhinoceros 5.0 software (Seattle, WA, USA) for measurement of the articular surface area of the lesser sigmoid notch. The surface area of the fragment attached to the olecranon was considered as the principle fragment and referred to as the proximal (dorsolateral) fragment. A polyline was drawn on the surface of the mesh reconstruction, after which the surface area within this polyline was measured using the Area command in Rhinoceros (Fig. 2). The articular surface area of each fragment was recorded and added to the area of the proximal fragment to determine the total lesser sigmoid articular surface area for each individual. The number of fracture fragments was also recorded, including the proximal fragment.

The fracture line location was determined by measuring the 3D polygon mesh reconstruction of the lesser sigmoid notch in its longest axis in Rhinoceros 5.0. This measurement was divided by 3 to identify upper, middle, and lower thirds. The lesser sigmoid fractures were then classified according to which third the fracture line traversed. When fracture fragments contributed to the longitudinal length of the lesser sigmoid notch, the linear distance across the fragment was measured and added to the distance across the intact lesser sigmoid notch to determine the length of the long axis. A fracture line was counted once for each third traversed. For instance, a fracture line found in the upper and middle third of the sigmoid notch was counted as one in the upper and one in the middle. This was done to better characterize fractures not confined by our arbitrarily divided lesser sigmoid notch. It also adjusted all fracture lines with different traversing direction into a single model.

Coronoid fracture type

Coronoid process fractures were classified according to Mayo types: type 1, transverse fracture of the tip; type 2, fracture involving the