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Association Between Injury Mechanism And The Type Of Posterior Complex Fracture-Dislocation Of The Elbow At Haji Adam Malik General Hospital, Medan

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ABSTRACT

Background: Posterior complex fracture-dislocation of the elbow is a severe traumatic injury involving elbow dislocation accompanied by fractures of important osseous stabilizers. The direction and energy of trauma may determine which stabilizing structures fail and, consequently, which fracture-dislocation pattern develops. However, clinical evidence directly evaluating the association between injury mechanism and specific posterior complex fracture-dislocation patterns remains limited, particularly in Indonesia.
Objective: To analyze the association between injury mechanism and the type of posterior complex fracture-dislocation of the elbow in adult patients treated at Haji Adam Malik General Hospital, Medan.
Methods: This analytical observational study used a cross-sectional design. A total of 48 adult patients with posterior complex fracture-dislocation of the elbow who met the study criteria were included. Data were obtained from medical records and radiological examinations during the period from January 1, 2020 to December 31, 2025. Injury mechanisms were categorized as fall on an outstretched hand (FOOSH) or direct injury. Radiological patterns were categorized as posterolateral, posteromedial, Monteggia apex anterior, Monteggia apex posterior, or trans-olecranon fracture-dislocation. Demographic variables included age, sex, body mass index (BMI), and injured side. Because the assumptions for the Pearson chi-square test were not fulfilled, the Fisher–Freeman–Halton exact test was used to assess the association.
Results: The mean age was 41.85 ± 14.76 years, with the largest age group being 30–39 years (25.0%). Men accounted for 52.1% of patients, 41.7% were overweight, and 75.0% sustained left-sided injuries. FOOSH was the predominant injury mechanism (64.6%), while direct injury accounted for 35.4%. The posterolateral pattern was most frequent (56.2%), followed by posteromedial (25.0%), Monteggia apex posterior (8.3%), trans-olecranon (8.3%), and Monteggia apex anterior (2.1%) patterns. Among FOOSH injuries, 83.9% were posterolateral, whereas direct injuries were predominantly posteromedial (47.1%), followed by Monteggia apex posterior (23.5%) and trans-olecranon (17.6%). The association was statistically significant ($p < 0.001$), with a strong effect size (Cramer's $V = 0.775$).
Conclusion: Injury mechanism was strongly associated with the type of posterior complex fracture-dislocation of the elbow. FOOSH was predominantly associated with posterolateral injury, whereas direct injury was more commonly associated with posteromedial, Monteggia, and trans-olecranon patterns. A detailed history of the injury mechanism may therefore assist early clinical suspicion, radiological evaluation, and treatment planning.

INTRODUCTION

Posterior complex fracture-dislocation of the elbow is a severe traumatic condition characterized by posterior, posterolateral, or posteromedial displacement of the forearm relative to the humerus together with fractures of important osseous stabilizers. The injury is clinically challenging because loss of bony congruity is often

accompanied by disruption of the capsule and collateral ligament complexes. The combination may produce substantial instability and predispose patients to stiffness, recurrent instability, pain, heterotopic ossification, and post-traumatic osteoarthritis when diagnosis or treatment is delayed.1,6,7

Elbow dislocation is the second most common major joint dislocation in adults after the shoulder and accounts for approximately 11%–28% of elbow injuries. Reported annual incidence varies among populations and definitions, with estimates ranging from approximately 2.9 to 9 per 100,000 persons. Simple dislocations constitute the majority of cases, whereas complex dislocations are less frequent but involve additional fractures of the radius, ulna, or humerus and generally represent more severe instability.6,8,10,11

The elbow is intrinsically stable because of the high congruence of the ulnohumeral articulation. Additional stability is provided by the radial head, coronoid process, medial collateral ligament (MCL), lateral collateral ligament complex (LCL), capsule, and dynamic muscular stabilizers. The anterior bundle of the MCL is an important valgus stabilizer, while the lateral ulnar collateral ligament is particularly important for posterolateral rotational stability.15–18,20,21

The pattern of fracture-dislocation is closely related to the direction and distribution of traumatic force. A fall on an outstretched hand (FOOSH) typically transmits axial load through the hand and forearm and may combine axial loading with valgus stress and forearm supination or external rotation. This mechanism is classically associated with posterolateral rotatory instability and the terrible triad, consisting of elbow dislocation, radial head fracture, and coronoid fracture.8,11,26,27

In contrast, axial loading combined with varus stress and internal rotation may produce posteromedial rotatory instability, commonly involving anteromedial coronoid fracture and injury to the lateral ligament complex. Direct high-energy trauma can produce different patterns, particularly injuries involving the olecranon and proximal ulna, including trans-olecranon and Monteggia-related fracture-dislocations.23,24,28,29

Although these biomechanical relationships are well described, most previous studies have focused on mechanisms, radiological classification, or treatment outcomes separately. Studies directly testing the association between an operationally defined mechanism of injury and specific fracture-dislocation types remain limited. The present study therefore aimed to determine whether FOOSH and direct injury were associated with distinct posterior complex fracture-dislocation patterns in adult patients treated at Haji Adam Malik General Hospital, a tertiary referral hospital in Medan, Indonesia.

MATERIALS AND METHODS

Study Design and Setting

This was an analytical observational study with a cross-sectional design. The study was conducted at Haji Adam Malik General Hospital (RSUP Haji Adam Malik), Medan, Indonesia. Data were obtained from medical records, the emergency department, and the Orthopaedics and Traumatology outpatient service. The case period covered January 1, 2020 through December 31, 2025.

Population and Sample

The target population comprised adult patients with posterior complex fracture-dislocation of the elbow. The accessible population consisted of adult patients diagnosed with this condition at Haji Adam Malik General Hospital during the study period. Consecutive sampling was used, and all eligible cases identified during the study period were included. The final sample comprised 48 patients.

Eligibility Criteria

Patients were eligible when they were at least 18 years of age, had medical-record documentation sufficient to classify the injury mechanism, had adequate elbow radiographs and/or computed tomography (CT) for evaluation of the injury pattern, and had sufficient baseline information on age, sex, and injured side. Patients with simple elbow dislocation without significant fracture, non-posterior dislocation outside the study focus, pathological fracture or dislocation, or previous major surgery, congenital deformity, or substantial pre-existing deformity of the ipsilateral elbow were excluded.

Variables and Operational Definitions

The independent variable was injury mechanism. FOOSH was defined as a fall in which the hand contacts the ground or another supporting surface and transmits force axially toward the elbow. Direct injury was defined as direct impact to the elbow or proximal forearm, including high-energy localized trauma. The dependent variable was the radiological type of posterior complex fracture-dislocation, classified as posterolateral, posteromedial, Monteggia apex anterior, Monteggia apex posterior, or trans-olecranon. Radiological assessment was based on anteroposterior and lateral elbow radiographs and CT when available. Potential confounding variables were age, sex, BMI, and injured side.

Data Collection and Statistical Analysis

Data were extracted from medical records and radiological examinations, coded, entered, checked, cleaned, and tabulated before analysis. Continuous data were assessed for distribution. Age was normally distributed based on the Shapiro–Wilk test ($p = 0.073$) and was therefore summarized as mean ± standard deviation. Categorical variables were summarized using frequencies and percentages. The association between injury mechanism and fracture-dislocation type was initially planned for analysis with the Pearson chi-square test. However, 7 of 10 cells (70.0%) had expected frequencies below 5, with a minimum expected frequency of 0.35. Therefore, the Fisher–Freeman–Halton exact test was used. Statistical significance was set at $p < 0.05$. Cramer's V was used to describe the strength of association.

Ethical Considerations

The thesis document states that ethical clearance was to be obtained from the Health Research Ethics Committee of Universitas Sumatera Utara before data collection and that patient confidentiality and the principles of the Declaration of Helsinki would be maintained. The present article does not add any ethical approval information beyond what is documented in the source thesis.

RESULTS

Demographic Characteristics

A total of 48 adult patients met the study criteria. The mean age was 41.85 ± 14.76 years, with a range of 18–68 years. The largest age group was 30–39 years (25.0%). Men comprised 52.1% of the sample and women 47.9%. Regarding BMI, 41.7% of patients were overweight, 31.2% were obese, and 27.1% had a normal BMI; no underweight patients were recorded. Left-sided injury was observed in 75.0% of patients and right-sided injury in 25.0%.

Characteristic	**n**	**%**
Age, mean ± SD (years)	41.85 ± 14.76	–
<20 years	2	4.2
20–29 years	9	18.8
30–39 years	12	25.0
40–49 years	9	18.8
50–59 years	7	14.6
≥60 years	9	18.8
Male	25	52.1
Female	23	47.9
Normal BMI	13	27.1
Overweight	20	41.7
Obesity	15	31.2
Right elbow	12	25.0
Left elbow	36	75.0

Distribution of Injury Mechanisms

FOOSH was the most frequent mechanism, accounting for 31 patients (64.6%), while direct injury accounted for 17 patients (35.4%). No other mechanism category was recorded in the final sample.

Injury mechanism	**n**	**%**
FOOSH	31	64.6
Direct injury	17	35.4
Total	48	100.0

Distribution of Fracture-Dislocation Types

The posterolateral pattern was the most common radiological type, occurring in 27 patients (56.2%), followed by posteromedial in 12 (25.0%). Monteggia apex posterior and trans-olecranon patterns each occurred in 4 patients (8.3%), while Monteggia apex anterior was the least frequent pattern, occurring in 1 patient (2.1%).

Fracture-dislocation type	**n**	**%**
Posterolateral	27	56.2
Posteromedial	12	25.0
Monteggia apex anterior	1	2.1
Monteggia apex posterior	4	8.3
Trans-olecranon	4	8.3
Total	48	100.0

Association Between Injury Mechanism and Fracture-Dislocation Type

The cross-tabulation demonstrated markedly different distributions between the two injury-mechanism groups. Among 31 patients with FOOSH, 26 (83.9%) had posterolateral fracture-dislocation, 4 (12.9%) had posteromedial injury, and 1 (3.2%) had trans-olecranon injury. No FOOSH patient had Monteggia apex anterior or apex posterior fracture-dislocation. Among the 17 patients with direct injury, posteromedial injury was the most frequent pattern (47.1%), followed by Monteggia apex posterior (23.5%), trans-olecranon (17.6%), posterolateral (5.9%), and Monteggia apex anterior (5.9%).

The Fisher–Freeman–Halton exact test demonstrated a statistically significant association between injury mechanism and fracture-dislocation type ($p < 0.001$). The source thesis additionally reports a Cramer's V of 0.775, indicating a strong association.

Mechanism	Posterolateral	Posteromedial	Monteggia apex anterior	Monteggia apex posterior	Trans-olecranon	Total
FOOSH	26 (83.9%)	4 (12.9%)	0 (0.0%)	0 (0.0%)	1 (3.2%)	31 (100%)
Direct injury	1 (5.9%)	8 (47.1%)	1 (5.9%)	4 (23.5%)	3 (17.6%)	17 (100%)
Total	27 (56.2%)	12 (25.0%)	1 (2.1%)	4 (8.3%)	4 (8.3%)	48 (100%)

Fisher–Freeman–Halton exact test: $p < 0.001$; Cramer's V = 0.775.

Distribution of Potential Confounders by Injury Mechanism

There were no statistically significant differences between the FOOSH and direct-injury groups with respect to age, sex, BMI, or injured side. Mean age was 42.1 ± 14.5 years in the FOOSH group and 41.4 ± 15.6 years in the direct-injury group ($p = 0.867$). Sex distribution ($p = 0.606$), BMI category ($p = 0.552$), and injured side ($p = 0.862$) were likewise comparable.

Variable	FOOSH (n=31)	Direct injury (n=17)	p value
Age, mean ± SD	42.1 ± 14.5	41.4 ± 15.6	0.867
Male	17 (54.8%)	8 (47.1%)	0.606
Female	14 (45.2%)	9 (52.9%)	
Normal BMI	10 (32.3%)	3 (17.6%)	0.552
Overweight	12 (38.7%)	8 (47.1%)	
Obesity	9 (29.0%)	6 (35.3%)	
Right elbow	8 (25.8%)	4 (23.5%)	0.862
Left elbow	23 (74.2%)	13 (76.5%)	

DISCUSSION

This study found a strong and statistically significant association between injury mechanism and the type of posterior complex fracture-dislocation of the elbow. The principal finding was the concentration of posterolateral injuries among FOOSH cases and the more heterogeneous distribution of posteromedial, Monteggia, and trans-olecranon patterns among direct injuries. The strength of association (Cramer's V = 0.775) suggests that the mechanism obtained during the initial history may have meaningful discriminatory value when clinicians anticipate the radiological injury pattern.

Demographic Characteristics

The mean age of 41.85 years and the predominance of the 30–39-year age group indicate that the study population was largely composed of adults in the productive age range. This finding is compatible with the concept that complex elbow injuries occur in physically active individuals exposed to occupational, transportation-related, and other traumatic events. Previous reports have described elbow dislocation across younger age groups, particularly when simple sports-related injuries are included; the older age distribution in the present study may therefore reflect the more severe and fracture-associated nature of the study population.6,10,11

Sex distribution was relatively balanced, with a slight male predominance (52.1%). This is similar to reports describing a modest male predominance in elbow dislocation, although other trauma cohorts have shown much stronger male predominance depending on occupational and sports exposure. The near 1:1 distribution in this study may reflect the broader referral population served by the hospital.

Overweight and obesity were common in the study population. However, BMI was evaluated as a potential confounder rather than as the primary exposure, and the study design does not support a causal conclusion that elevated BMI determines a particular fracture-dislocation pattern. The lack of a significant difference in BMI distribution between mechanism groups ($p = 0.552$) also suggests that BMI did not materially account for the observed mechanism-pattern association.

Left-sided injury occurred in 75.0% of cases. This finding may be compatible with the concept that the non-

dominant upper limb can be used protectively during a fall, although hand dominance was not consistently documented in the medical records. Consequently, the side-of-injury finding should be interpreted cautiously rather than as evidence of a universal left-sided predisposition.

Injury Mechanism

FOOSH was the dominant mechanism, occurring in 64.6% of patients. This is consistent with the established role of falls on an outstretched hand in elbow dislocation. The mechanism transmits axial force from the hand through the forearm to the elbow, while the exact injury pattern depends on elbow position and additional valgus, varus, and rotational components. Previous studies have also identified falling onto an outstretched arm as a frequent mechanism of acute elbow dislocation.5,6,8,11

Direct injury accounted for 35.4% of cases. Direct high-energy trauma is particularly relevant to complex patterns involving the proximal ulna. Trans-olecranon fracture-dislocation, for example, has been associated with high-energy trauma and substantial osseous disruption.28,29 The relatively high proportion of direct injuries in this tertiary trauma population may therefore reflect referral of high-energy injuries.

Radiological Distribution

Posterolateral fracture-dislocation was the most frequent pattern (56.2%), followed by posteromedial fracture-dislocation (25.0%). The predominance of posterolateral injury is consistent with the general observation that posterior and posterolateral elbow dislocation patterns are common. Complex posterolateral injuries may include the terrible triad, in which radial head and coronoid fractures accompany dislocation.7,24,26

The posteromedial, Monteggia, and trans-olecranon patterns were less frequent but clinically important. These patterns represent different configurations of osseous and ligamentous failure and may require different operative strategies. The distinction is therefore more than descriptive: identifying the pattern helps clinicians anticipate which stabilizing structures may have failed.

FOOSH and Posterolateral Injury

The strongest descriptive relationship in the study was between FOOSH and posterolateral fracture-dislocation. Of the 31 FOOSH patients, 26 (83.9%) had the posterolateral pattern. This relationship has a coherent biomechanical explanation. During a fall on an outstretched hand, axial loading can combine with valgus stress and forearm supination or external rotation. These forces place substantial stress on the lateral ligament complex and can initiate posterolateral rotational instability. Continued transmission of energy may result in radial head impaction and coronoid injury, producing a terrible-triad-type pattern.8,11,26,27

The classic Horii-circle concept similarly describes progressive disruption beginning laterally and extending through the capsule and, with greater energy, to medial structures. Although the precise sequence of tissue failure is not identical in every patient, the model remains useful for explaining why a FOOSH mechanism often produces posterolateral instability. The present clinical distribution is therefore consistent with established biomechanical concepts.

FOOSH should not, however, be regarded as a deterministic mechanism. A FOOSH event accompanied predominantly by varus force and internal rotation can produce posteromedial rotatory instability. The four FOOSH patients with posteromedial injury in the present study illustrate this principle and support the interpretation that the mechanism category is a probabilistic indicator rather than an absolute predictor.

Direct Injury and Posteromedial, Monteggia, and Trans-olecranon Patterns

Direct injury showed a different distribution. Posteromedial fracture-dislocation was the most frequent pattern in this group (47.1%), followed by Monteggia apex posterior (23.5%) and trans-olecranon (17.6%). Direct trauma may concentrate energy around the elbow and proximal forearm, producing osseous failure that differs from the progressive ligamentous failure commonly described for classic FOOSH injuries.

Posteromedial injury is biomechanically related to axial loading combined with varus force and internal rotation. This configuration may fracture the anteromedial facet of the coronoid and disrupt the lateral ligament complex, producing varus/posteromedial instability.23,24,28 The predominance of posteromedial injury among direct-trauma patients in this cohort is compatible with this mechanism, although the medical-record classification did not capture the precise force vectors in each event.

Monteggia-related injuries are associated with proximal ulnar fracture and disruption of the radiocapitellar relationship. Axial loading combined with a bending moment can produce this pattern, while apex-posterior injuries may be associated with posteriorly directed forces.23,24 The concentration of all four Monteggia apex-posterior cases in the direct-injury group supports the clinical value of asking specifically about localized high-energy impact to the elbow or proximal forearm.

Trans-olecranon fracture-dislocation is characterized by ulnohumeral incongruity through olecranon fracture while

the proximal radioulnar joint remains intact. High-energy trauma is commonly implicated.28,29 In the present study, three of four trans-olecranon cases occurred after direct injury, supporting the relationship between localized high-energy trauma and proximal-ulnar fracture-dislocation.

Strength and Clinical Meaning of the Association

The Cramer's V of 0.775 indicates a strong association between injury mechanism and fracture-dislocation type. This finding is clinically relevant because the injury mechanism is usually available before advanced imaging. A patient reporting a FOOSH mechanism may prompt focused assessment of the radial head, coronoid, and lateral ligament complex, whereas a history of direct high-energy impact may increase suspicion for posteromedial, Monteggia, or trans-olecranon injury.

Nevertheless, the association should be interpreted as probabilistic. A retrospective operational classification of mechanism cannot reproduce the full biomechanical complexity of trauma. The exact position of the elbow, forearm rotation, direction of impact, velocity, and energy transfer were not consistently available. Therefore, mechanism should complement rather than replace radiological evaluation.

Potential Confounders

Age, sex, BMI, and injured side did not differ significantly between the FOOSH and direct-injury groups, with p values of 0.867, 0.606, 0.552, and 0.862, respectively. These findings indicate that the measured demographic characteristics were relatively balanced between mechanism groups. This supports, but does not prove, the interpretation that the observed mechanism-pattern association was not primarily driven by differences in these variables.

The absence of statistical significance should not be interpreted as proof that these characteristics never influence elbow injury patterns. The sample size was limited, and a larger multicenter cohort could identify smaller interactions or effect modification that this study was underpowered to detect.

Clinical Implications

The findings support systematic documentation of injury mechanism in patients presenting with traumatic elbow injury. In a patient with FOOSH, clinicians should maintain a high index of suspicion for posterolateral fracture-dislocation and terrible-triad components, including radial head and coronoid injury. In patients with direct high-energy trauma, attention should be directed toward the anteromedial coronoid, olecranon, proximal ulna, and possible Monteggia-related injury.

Radiographs remain essential, but CT may be particularly useful when complex fracture morphology is suspected, when small intra-articular fragments are difficult to characterize on plain radiographs, or when the clinical history suggests a high-energy injury. A mechanism-informed imaging strategy may improve recognition of injuries that could otherwise be underestimated.

Limitations and Future Research

Several limitations should be considered. First, the sample size was small (n = 48), and several cross-tabulation cells had low expected frequencies. Although the Fisher–Freeman–Halton exact test appropriately addressed this issue, subgroup estimates remain imprecise. Second, the study was retrospective and relied on documentation in medical records; the operational categories FOOSH and direct injury do not fully capture axial, valgus, varus, rotational, and bending components. Third, hand dominance was not consistently documented, limiting interpretation of the left-sided predominance. Fourth, the single-center tertiary-hospital setting limits generalizability.

Future studies should use prospective, multicenter designs with larger samples and standardized documentation of trauma position, energy, direction of impact, hand dominance, radiological morphology, intraoperative findings, treatment, and functional outcomes. Multivariable modeling could then determine whether injury mechanism independently predicts specific fracture-dislocation patterns and could support development of a mechanism-based diagnostic algorithm.

CONCLUSION

There was a strong and statistically significant association between injury mechanism and the type of posterior complex fracture-dislocation of the elbow in adult patients treated at Haji Adam Malik General Hospital, Medan. FOOSH was the predominant mechanism and was strongly associated with posterolateral fracture-dislocation, whereas direct injury showed a more heterogeneous distribution dominated by posteromedial, Monteggia apex posterior, and trans-olecranon patterns. Age, sex, BMI, and injured side were not significantly different between mechanism groups. These findings indicate that a careful history of the trauma mechanism can provide clinically useful information for early suspicion of the injury pattern and may assist subsequent radiological assessment and treatment planning.

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