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Epidemiology of isolated olecranon fractures: a detailed survey on a large sample of patients in a suburban area

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\textbf{Running title:} Epidemiology of isolated olecranon fractures

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Abstract

Background: Literature lacks data concerning several epidemiologic aspects of isolated olecranon fractures (IOFs). The few studies that have analyzed this type of fracture show a low sample size and contradicting results.

Methods: This retrospective study included 165 consecutive patients (82 men, 83 women) who sustained an IOF in the past 10 years. Participants who were aged <16 years or had a previous elbow fracture or had a fracture that involved other bones of the elbow joint, were excluded. Data regarding age, sex, season, date, and fracture side were collected. According to the mechanism of injury, we arbitrarily distinguished 7 subgroups. IOFs were classified according to the MAYO and AO classifications using x-ray. Statistics were performed.

Results: The patients mean age was 58.5 (SD, 21.3) years, and men and women were aged 48.1 (SD, 19.8) years and 67.9 (SD, 18.8) years, respectively. The most frequent fracture patterns were the MAYO 2A and the AO 2U1B1(d). Low-energy mechanisms caused simple dislocated-stable fractures while high-energy mechanisms caused both simple and comminuted displaced-stable fractures. Significant differences in the trauma mechanism were found between male and female patients. In the former fractures showed a bimodal distribution depending on the patients’ age group whereas in females the traumatic event was mainly represented by a low-energy mechanism. Overall, the most common cause of fracture was a low-energy accident. The seasonal distribution of fractures was different for male and female patients being more frequent in summer among young males and more frequent in winter among the elderly, both males and females. The left side was involved in 87 patients.

Conclusions: IOFs occur equally in both genders although with different age distribution. The most common fracture pattern was a simple displaced-stable fracture (MAYO 2A and AO 2U1B1(d)). Young males are more often subject to high-energy injuries that occur in road accidents while with aging they become more prone to fragility fractures as women. Female
patients are usually older and are mostly affected by low-energy traumas as a fall from standing height.

Level of evidence: Level IV; Case Series; Descriptive Epidemiology Study

Keywords: isolated olecranon fractures; olecranon fractures epidemiology; proximal forearm fractures; MAYO classification; AO classification; proximal ulna trauma mechanisms

Olecranon fractures (OFs) represent approximately 10% of all elbow and 20% of proximal forearm fractures, respectively, and are also the most common type of proximal ulna fracture. According to literature the incidence of this type of fracture varies from 11.5 to 12 per 100,000 population and it can be caused by various traumatic mechanisms both direct and indirect, although the former seems more frequent. Many authors have studied the management and postoperative follow-up of these lesions, however, very few studies have analyzed in depth the epidemiology of this fracture and those studies that have, show a low sample size and contradictory results. Data collected in two of the most representative studies about OFs epidemiology differ greatly for sex, age, and mechanism of trauma. Duckworth et al studied 78 fractures of the proximal ulna of which 64 of the olecranon and found that these were more frequent among elderly females who reported a low energy fall at home or in the street. On the contrary, Nieto et al, who studied 98 IOFs, found that patients were mainly young and active males, and the most common type of injury were road traffic accidents.

The goal of this study is to analyze a large number of patients with IOF that occurred in the last 10 years in a suburban area and to provide a detailed epidemiologic survey.
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Materials and methods

We have conducted a retrospective search of the IOFs that were registered in the database of the local Emergency Department which serves an area of more than 550,000 inhabitants. To carry out the research we have used the International Statistical Classification of Diseases and Related Health Problems, Ninth Version codes. In particular, we have used the codes for “closed olecranon fractures” (81301) and “open olecranon fractures” (81311). The database was maintained on a digital platform.

Two authors (M.C. and C.V.) collected information regarding sex, age, date of fracture, mechanism of injury and fracture side. Trauma mechanisms were divided in 7 subgroups: 1, low-energy trauma occurred at home; 2, low-energy trauma occurred in an urban environment (when walking, running); 3, work-related injuries; 4, trauma resulting from direct hit; 5, high-energy trauma resulting from high fall; 6, sports trauma; 7, high-energy trauma resulting from car, motorcycle, public transport, and pedestrian accidents. In order to facilitate the statistical analysis, mechanisms 1 and 2 were grouped as low-energy (MEC-L) while mechanisms 5, 6, and 7 as high energy (MEC-H) mechanisms of trauma.

In order to evaluate the correlation among parameters, patients were divided into 3 subgroups according to age: (1) patients aged between 16 and 45 years, (2) patients aged between 46 and 75 years, and (3) patients older than 76 years.

All fractures were assessed using x-ray standard elbow trauma series consisting of a true anteroposterior view, a lateral view, and an oblique view. In three cases (1.8%) which showed a stable fracture the diagnosis was made with CT-scans because simple x-rays were dubious.

A total of 110 patients with an olecranon fracture were excluded from the study. These included patients younger than 16 years and those who presented a fractured capitellum and/or coronoid process or previous elbow surgical treatments.
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IOFs were classified using the MAYO and the AO classification systems. Each fracture was classified twice by 3 authors (G.S., C.M. and C.V.) at 3-month interval. Intra-rater and inter-rater reliability were statistically assessed.

According to our Country laws, this study does not need the ethical committee approval.

Statistical analysis

A descriptive analysis was performed for all examined parameters. Exact F Fisher test was used to identify any difference between age, mechanism of trauma, time of year of the injury and fracture pattern when analyzing male and female patients both together and separately.

Intra and inter-rater reliability were studied with κ statistics according to Cohen. The κ values for intra-rater reliability were calculated for each observer before the mean κ value was obtained. The κ values for inter-rater reliability were calculated for each possible pair of the 3 observers before the mean κ value was obtained. The Landis and Koch criteria were used to assess the obtained data. The κ values are reported as mean and 95% confidence interval (CI).

The level of significance was set at alpha ≤ 0.05. IBM SPSS Statistics for Windows 20.0 software (IBM, Armonk, NY, USA) was used.

Results

A total of 165 consecutive patients managed in the ED of our hospital for IOF from January 30, 2011, to January 30, 2021, were selected out of a total of 32,400 fractures. The number of male patients was 82 (49.7%) while females were 83 (50.3%).

The patients mean age was 58.5 (SD, 21.3) years, and men and women were aged 48.1 (SD, 19.8) years and 67.9 (SD, 18.8) years, respectively. The left side was more frequently involved (87 cases, 52.7%) (p = 0.53).
All 165 IOFs were classified using the MAYO \(^2, 14\) and the AO/OTA (Association Arbeitsgemeinschaft Für Osteosynthesefragen) \(^8, 9\) classification systems. The former classification divides fractures into three types (I, II and III) depending on the stability and the displacement shown on the X-rays and each type is further divided into uncomminuted (A) and comminuted (B). The AO classification assigns a number to every bone of the body (ulna is 2U) and an additional number to identify if the fracture involves the proximal (1), diaphyseal (2) or distal (3) segment of the bone. The end segments fractures are divided in extraarticular (A), partial articular (B) and complete articular (C). An ulterior qualification can be added depending on the characteristics of the fracture varying in the different bones.

The most frequent patterns of fracture according to the MAYO system were 2A (64.24%), 2B (26.06%), 1A (7.27%), 3B (1.21%), 3A (0.61%) and 1B (0.61%), whereas for the AO system were 2U1B1(d) (73.94%) and 2U1B1(e) (26.06%). Only 3 patients had an open fracture, accounting for 1.8% of IOFs. When considering all patients, MAYO IIa fractures were more frequently caused by low-energy mechanisms whereas type 2B were a consequence of both low- and high-energy injuries \((p = 0.047)\) (Fig. 1). Among male patients, type 2B fractures were observed especially in patients aged between 16 and 45 years \((p = 0.021)\) and high-energy mechanisms of trauma were associated to MAYO 2B \((p = 0.01)\) and AO 2U1B1(e) \((p = 0.031)\) fractures. Elbow dislocation was observed in 2 patients (1.21%) and were associated with a 2A (2U1B1d) and 3A (2U1B1d) fracture pattern.

Fig. 2 shows the distribution of IOFs in males and females according to the trauma mechanism. In women the most frequent type of injury was represented by low-energy traumatic events, whereas in men by high-energy mechanisms \((p < 0.001)\). When considering age groups, the most frequent cause of injury was a high-energy trauma in patients aged 17 to 75 years and a low-energy trauma in older patients \((p < 0.001)\).
Male patients showed a bimodal distribution of the fracture mechanism. A high-energy mechanism (5,6 and 7) was observed in 59.7% of patients between 17 and 75 years old, while a low-energy mechanism (1 and 2) was found in 80% of patients older than 76 (p = 0.02) (Fig. 3).

The trauma mechanism in female patients was mainly represented by low-energy injuries (1 and 2), involving 68.1% of patients aged < 75 years and 97.4% of patients aged > 75 years (p < 0.001) (Table I).

Analyzing the seasonal distribution of fractures, low-energy mechanisms appeared well represented all year round, but especially in winter, while high-energy injuries mainly occurred in summer (p = 0.007) (Fig. 4). The seasonal distribution of IOFs in males and females is shown in Fig. 5: IOFs occurred more frequently in winter and summer seasons although with an inverse distribution between males and females. In males high and low energy fractures were more frequent in summer and winter, respectively (p = 0.03). During the other periods of the year the prevalence of IOFs was lower (< 17%). No significant differences were found between male and female patients when considering bimesters or seasons (p = 0.33 and p = 0.14).

No significant differences were observed when analyzing the day of the week.

The mean κ value for intraobserver reliability assessment was 0.97 (95% CI, 0.96-0.98) while the mean value for interobserver reliability was 0.93 (95% CI, 0.91-0.95).

**Discussion**

To date few studies have analyzed the epidemiology of IOFs. In particular, how the traumatic mechanism is correlated with age, sex, seasons, and weekdays has not been studied in detail. In our study the goal was to further investigate all these aspects in order to achieve a better knowledge of this fracture. IOFs represent the most common fractures of the elbow.\(^5\)\(^6\)\(^11\) In 2002, Karlsson et al \(^6\) in a follow-up study on just 73 patients found that the incidence of this type of
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fracture is of 11.5 per 100,000 population, which was comparable with the findings of Duckworth et al \(^5\) that in a retrospective study on 64 patients found an incidence of 12 per 100,000 population.

According to literature IOFs are mostly fragility fractures caused by low-energy falls and affect more frequently women and elderly patients; \(^3\)-\(^6\), \(^1^6\) however, in Niéto et al \(^1^1\) study the main mechanism of trauma was represented by high-energy road traffic accidents and overall men were more affected than women. As in Duckworth’s study \(^5\) we found that in women the mean age (67.9 years) was considerably higher than in males (mean age, 48.1 years), and this may be due to the longer life expectancy and to the higher incidence of osteoporosis.

Most of the authors that studied olecranon fractures used the MAYO classification system. \(^2\), \(^1^4\) In 2014 Tamaoki et al \(^1^5\) compared different classification systems for OFs and concluded that the best method for both interobserver and intraobserver reliability were the MAYO and the AO classification systems. In our study we have decided to use both these methods using x-rays and CT scans where possible.

Overall, the most frequent patterns that we found were the MAYO 2A and the AO 2U1B1(d) (64.2% and 74%, respectively) as observed in other studies. The trauma mechanism influenced the fracture pattern, especially when according to MAYO classification. In fact, we found a statistically significant difference among the different patterns and more precisely low-energy mechanisms caused simple dislocated-stable fractures (2A) whereas high-energy mechanisms caused comminuted displaced-stable fractures (2B and 2U1B1(d)).

Regarding the mechanism of trauma, IOFs are caused by both direct and indirect trauma although the former is more common. In 1995 Amis et al \(^1\) conducted a study on forty cadaveric elbows that were mounted onto a purpose-built impact loading rig and were then fractured with a swinging impactor pendulum; the authors found that the olecranon was easily fractured when directly impacted in the 60° to 110° arc of flexion. We found a statistical difference between
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men and women. High-energy mechanisms such as sports accidents, high falls and motor vehicle collisions were overall the most frequent cause of IOFs in men while a low energy mechanism as a fall from standing height at home or in the street represented the most common mechanism amongst women. No differences in prevalence were found between males and females when considering workplace and direct hit injuries. These results may be related to several aspects such as the longer time spent at home, longer life expectancy, reduced muscular strength, gait disorders and higher incidence of severe osteoporosis that characterize elderly women. In males, as observed in other studies regarding upper extremity fractures, a bimodal age distribution according to trauma mechanism was detected, with almost 60% of patients aged 17 to 75 who were injured by a high energy mechanism (MEC-5, 6 and 7), while a low-energy mechanism (MEC-1 and 2) was found in 80% (n = 8) of patients older than 76. These results may be related to the fact that younger patients are more frequently involved in motor vehicle collisions (MVC), especially motorcycle accidents (34% of all high-energy injuries and 55.5% of all MCV) whereas older patients are more prone to low-energy traumas probably as a consequence of the lower bone density associated with aging. Since in both male and female elderly subjects these fractures are mainly caused by low energy mechanisms it is reasonable to consider them as primary fractures related to an underlying osteoporotic condition which may require adequate preventative therapy in order to reduce the risk of future and more serious fragility fractures.

When considering the mechanism and the time of the year, high energy trauma showed a greater frequency in summer as the result of a greater use of motorcycles and bicycles in this season, whereas winter was mainly characterized by low-energy injuries. This is particularly true for male patients, and this may be related to the different age distribution of injured patients during the year.
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In our study we found that IOFs were more frequent in winter and summer seasons, although women were more affected in the former and males in the latter. These data may be related to the weather conditions and to people’s habits. Probably in summer people travel more resulting in an increased number of accidents, while in winter the fewer hours of sunlight could increase the risk of falls in both domestic and urban environments.

Our study presents one main limit represented by the use of conventional x-rays (98.2% of cases). CT was considered a second stage diagnostic tool prescribed only in case of diagnostic doubts.

Conclusions

This epidemiologic study on a large sample demonstrated that IOFs are equally frequent in men and women and that the main patterns of fracture in both genders and in all age groups are MAYO 2A and AO 2U1B1(d). Female patients showed a higher mean age and an increasing prevalence of fractures with aging. Males presented a lower mean age and a bimodal distribution depending on the mechanism of trauma.

This study also showed that the mechanism of fracture and the season in which it occurred are different for male and female patients. In the former the main mechanism is represented by a high-energy injury that occurred mainly in summer, while in the latter the main cause of injury was a low-energy trauma that happened in winter.

References

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Table and figure legends

**Figure 1:** Fracture patterns according to MAYO classification

**Figure 2:** Distribution of isolated olecranon fractures in both genders according to the mechanism of trauma

**Figure 3:** Distribution of fractures in males according to the mechanism of trauma

**Figure 4:** Seasonal distribution of injuries according to the mechanism of trauma

**Figure 5:** Seasonal distribution of olecranon fractures in males and females

**Table I:** Distribution of olecranon fractures in females according to age group and mechanism of trauma
<table>
<thead>
<tr>
<th>Age group</th>
<th>Mechanism of trauma</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEC-H</td>
<td>MEC-L</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>68</td>
</tr>
</tbody>
</table>
The bar chart shows the distribution of MEC-H (High-energy), MEC-L (Low-energy), MEC3 (Work-related), and MEC4 (Direct hit) across winter, spring, summer, and autumn.

- **Winter**:
  - MEC-H: 35
  - MEC-L: 5
  - MEC3: 2
  - MEC4: 1

- **Spring**:
  - MEC-H: 10
  - MEC-L: 15
  - MEC3: 5
  - MEC4: 0

- **Summer**:
  - MEC-H: 20
  - MEC-L: 30
  - MEC3: 10
  - MEC4: 0

- **Autumn**:
  - MEC-H: 15
  - MEC-L: 25
  - MEC3: 5
  - MEC4: 0
Cantore Matteo: conceptualization, validation, formal analysis, investigation, data curation, writing - original draft, writing - review & editing, visualization.

Candela Vittorio: validation, investigation, resources, data curation, writing - original draft, visualization.

Sessa Pasquale: formal analysis, data curation.

Giannicola Giuseppe: conceptualization, resources, supervision, writing - review & editing.

Gumina Stefano: conceptualization, methodology, validation, investigation, resources, writing - original draft, writing - review & editing, visualization, supervision, project administration.