PRONATION INJURIES OF THE FOREARM

with Special Reference to the Anterior Monteggia Fracture

E. Mervyn Evans, Birmingham, England

From the Birmingham Accident Hospital

The exact mechanism of an injury is often difficult to determine. A patient with a severe fracture of the forearm is seldom able to give precise details of his accident, and the mechanism of many such fractures is thus still unknown. Why, for instance, should one child sustain a greenstick fracture of the lower ends of the radius and ulna, another a separation of the epiphysis of the head of the radius, and yet another a supracondylar fracture of the humerus, all from apparently similar falls on the outstretched hand? The answer surely must be that a number of other factors are involved, such as the position of the elbow at the time of impact, the direction in which the body is falling, and so on.

![Fig. 1]

With a fall forward on to the hand the forearm is pronated and the hand is palm downwards. If the body is twisting outwards at the moment of impact, a strong pronation force is transmitted through the humerus to the forearm.

![Figs. 2-5]

Diagrams illustrating the mechanism of pronation injuries of the forearm. The bones of the right forearm are seen from the lateral aspect. In pronation, the radius and ulna cross near the junction of their upper and middle thirds (Fig. 2). The ulna may be fractured either by the rotation force shown here or by angulatory strain. At the same time the upper third of the ulna acts as a fulcrum over which the upper end of the radius is forced forwards if the pronation force continues (Fig. 3). The result is either dislocation of the head of the radius (Fig. 4) or a transverse fracture near its upper end (Fig. 5).

When a patient falls forward on to the outstretched hand the forearm is already pronated and at the moment of impact the hand becomes relatively fixed to the ground. To the downward momentum of the falling body a rotation force is added when twisting of the trunk causes external rotation of the humerus and ulna (Fig. 1). If this force continues until the normal range of pronation at the radio-ulnar joints is expended, something must give. The ulna cannot rotate, because it is fixed below by the ulnar carpal ligament and above by its articulation with the humerus. The ulna is therefore liable to fracture, and the combination of the rotation force and of the bending force set up by longitudinal compression
PRONATION INJURIES OF THE FOREARM

may produce an oblique, transverse or butterfly fracture in accordance with the principles set out by Messerer (Figs. 2 to 5). At the same time the radius is forced into extreme pronation and lies across the ulna, at the junction of the upper and middle thirds. As the ulna fractures, the two bones come into contact, and the point of contact forms a fulcrum over which the upper end of the radius is forced forward. As the pronation force continues, the radius is either levered forward out of the superior radio-ulnar joint or is fractured in its upper third.

On theoretical grounds, then, one would expect forced pronation to cause one of three injuries, all of which are well-known: 1) fracture of the ulna in its middle third with backward angulation and anterior dislocation of the head of the radius—the anterior Monteggia fracture; occasionally the head or epiphysis of the radius is damaged at the same time; 2) fracture of the ulna as above with a high fracture of the shaft of the radius; 3) anterior dislocation of the head of the radius without fracture of the ulna.

THE ANTERIOR MONTEGGIA FRACTURE

Although forced pronation may cause any of the injuries mentioned, and probably others (Fitzgerald 1947), this paper is concerned mainly with the anterior Monteggia fracture, the treatment of which has long been considered difficult (Fig. 6). Watson-Jones (1943) stated that it caused permanent disability in 85 per cent. of adults in a series of cases treated by many surgeons and gave a formidable list of complications. He advised open reduction and plating of the ulna with post-operative fixation in a plaster spica.

Closed reduction and immobilisation in supination have been mentioned in the literature by several authors. Speed and Boyd (1940) advocated plating of the ulna with repair of the superior radio-ulnar dislocation by a fascial sling, but they stated that in children and sometimes in adults the injury might be reduced by manipulation. In such cases they advise supination "to relax the biceps and supinator muscles and so diminish the upward pull of the biceps on the radial head and the radial pull on the ulna by the supinator." Wise (1941) reported a case of lateral dislocation of the head of the radius with fracture of the ulna treated by open reduction and noted that the dislocation was reduced by traction and supination. Consistently good results by closed methods have been reported only by Naylor (1942) who advocated traction and pronation with the elbow flexed 90 degrees and, if this failed, traction in flexion and supination.

Nevertheless the primary importance of supination has not been emphasized up to the present.

**Mechanism**—Most authorities consider the injury is due to a direct blow on the back of the forearm which fractures the ulna at the point of impact and forces the head of the radius forward. While it is possible that this may sometimes occur, there are several reasons for believing it to be exceptional:

1) At the site of fracture the ulna is subcutaneous and, if the fracture were due to direct violence, one would expect to find severe bruising or breaking of the skin at the point of impact. In no case in the present series was this so; one case was indeed compound, but the ulna had penetrated the skin anteriorly well away from the supposed point of impact. In support of his belief that the injury is due to direct violence, Naylor stated that there was considerable bruising at the site of the ulnar fracture which in a large proportion of cases was said to be compound. Nevertheless in the only case of compound fracture reported in detail in

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*Fig. 6 An old case of Monteggia fracture illustrating non-union of the ulna and anterior dislocation of the head of the radius with a plaque of calcification.*

Vol. 31 B, No. 4, November 1949.
his review the wound was also on the anterior aspect of the forearm. Figure 7 is a photograph of a patient taken on admission; the skin over the ulna is unmarked.

2) If the fracture of the ulna were due to direct violence one would expect more comminution than is usually seen. In the Monteggia fractures reported here the pattern of the fracture was that which one would expect from either a rotation strain or from a longitudinal compression force; in no case was the fracture comminuted.

3) When patients have given a clear history of a blow on the back of the forearm, the injury sustained has been either a fracture of the shaft of the ulna or fractures of the shafts of both bones at roughly the same level, but in no case a forward dislocation of the head of the radius.

4) Finally, dissected specimens show clearly that the capsule of the superior radio-ulnar joint is strong anteriorly and is protected by the supinator brevis and brachialis muscles. It seems unlikely that a direct blow would be sufficient to cause dislocation, especially if some of the force were spent in fracturing the ulna; a twisting force, increased by leverage action as the radius crosses the ulna in pronation, would be much more likely to do so.

Confirmatory evidence of the mechanism of the Monteggia fracture is shown in the case illustrated in Figure 8. The lateral view of the forearm in neutral rotation shows tilting of the epiphysis of the head of the radius in addition to anterior dislocation. It is well known that such epiphysial displacements are caused by the head of the radius striking the capitellum while a valgus strain is being thrown on the joint, and that the epiphysis always tilts laterally. Here in neutral rotation the epiphysis is tilted backward, indicating that the radius has been externally rotated through 90 degrees from the position of full pronation at the moment of injury.

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tr>
<td><strong>Results of Pronation Strain on the Forearm in Eighteen Specimens</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Cases</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Fracture of the ulna in its middle third and anterior dislocation of the head of the radius (the anterior Monteggia fracture)</td>
</tr>
<tr>
<td>3</td>
<td>Fracture of the ulna in its middle third and transverse fracture of the radius just below the tuberosity</td>
</tr>
<tr>
<td>2</td>
<td>Anterior dislocation of the head of the radius without fracture of the ulna</td>
</tr>
<tr>
<td>1</td>
<td>Dislocation of the elbow</td>
</tr>
</tbody>
</table>
Experimental work—In an attempt to determine the mechanism of the anterior Monteggia fracture, experiments were carried out on eighteen dissecting-room specimens. The procedure was as follows: the soft tissues were removed from the elbow and forearm, leaving only the capsule and ligaments and the interosseous membrane; the shaft of the humerus was held firmly in a vice and the forearm was gripped in a wooden clamp just above the wrist and slowly pronated. A typical experiment is shown in Figures 9 to 11 and the results are shown in Table I.
In the twelve cases in which a Monteggia fracture was produced, it was interesting to find that the ulna always fractured first and as pronation continued the head of the radius was screwed forward out of its joint. The capsule began to rupture slowly strand by strand and then suddenly split, allowing the dislocation to become complete.

If these injuries are caused by a pronation force one would expect reduction to be achieved by supination. This was observed consistently in the experiments (Figs. 12–13). Whether the ulna was fractured or not, the head of the radius was reduced by supination—it was "screwed out" in pronation and "screwed home" in supination.

![Fig. 12](image)

In this experiment pronation caused dislocation of the head of the radius without fracture of the ulna. Figure 12 shows the specimen in pronation with the radial head dislocated. By supinating the forearm the dislocation was easily reduced (Fig. 13).

**CLINICAL MATERIAL**

Monteggia fractures are uncommon and in the last two years the author has been able to collect only eleven. This gives an incidence which corresponds roughly with that reported by Naylor. The investigation and management of these cases were as follows: Under general anaesthesia and with the patient lying supine the arm was held abducted at the shoulder and the elbow flexed 90 degrees. Lateral radiographs of the forearm were taken in supination, mid-rotation and pronation. In most patients full supination reduced both the superior radio-ulnar dislocation and the deformity of the ulna; with one exception reduction was most nearly complete in supination. When necessary, reduction was completed by traction on the hand and direct pressure over the radial head. After reduction had been secured an above-elbow plaster was applied and the final position was confirmed radiographically. At the end of treatment the elbow was radiographed in three rotational positions to assess the stability of the superior radio-ulnar joint. The results are summarised in Table II and illustrative cases are shown in Figures 14 to 32.
## TABLE II
A Summary of Eleven Cases of Pronation Injury of the Forearm

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Injury</th>
<th>Mechanism</th>
<th>Reduction</th>
<th>Result</th>
<th>Range of Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal side</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Supination</td>
</tr>
<tr>
<td>1</td>
<td>49</td>
<td>Simple Monteggia</td>
<td>Unknown</td>
<td>Supination</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>105</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>Simple Monteggia</td>
<td>Fell from a tram. Exact mechanism unknown</td>
<td>Supination</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>Simple Monteggia</td>
<td>Knocked down by car. Fell on to outstretched hand</td>
<td>Supination and pressure</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>Simple Monteggia</td>
<td>Fell off bicycle on to outstretched hand</td>
<td>Open reduction at two weeks and supination</td>
<td>Union of ulna. Radio-ulnar subluxation</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Simple Monteggia</td>
<td>Fell off bicycle. Exact mechanism unknown</td>
<td>Neutral rotation and pressure on head of radius</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>Full</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Compound from within. Monteggia</td>
<td>Fell at play. Mechanism unknown</td>
<td>Supination</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Simple Monteggia</td>
<td>Unknown</td>
<td>Supination</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>Full</td>
</tr>
<tr>
<td>8</td>
<td>71</td>
<td>Fracture lower third radius. Superior radio-ulnar dislocation</td>
<td>Fell on to hand Mechanism unknown</td>
<td>Radius plated. Radio-ulnar dislocation in full supination</td>
<td>Union of radius. Radio-ulnar joint stable</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>Anterior dislocation head of radius</td>
<td>Unknown</td>
<td>Supination</td>
<td>Stable</td>
<td>Full</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Separation upper radial epiphysis and anterior dislocation superior radio-ulnar joint</td>
<td>Caught sleeve in machine: hand rotated into full pronation and body twisted round several times</td>
<td>Open reduction in full supination</td>
<td>Stable</td>
<td>100</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>Simple Monteggia</td>
<td>Unknown</td>
<td>Supination</td>
<td>Union of ulna. Radio-ulnar joint stable</td>
<td>Full</td>
</tr>
</tbody>
</table>

The ranges of rotation movement are shown as one would see them when examining a patient. The measurements were taken with Patrick's goniometer, but mid-rotation is recorded as 0 degrees.
Case 1. W. C., aged forty-nine years. Fracture of the ulna with anterior dislocation of the head of the radius. Figure 14 shows the position in full pronation and Figure 15 in mid-rotation. Reduction was secured only after full supination with long-axis traction (Figure 16). Note how the ulnar fragments fell together in this position.

Case 1, continued. Eight weeks later the fracture was united and the superior radio-ulnar joint was stable in all positions of rotation: Figure 17, full pronation; Figure 18, mid-rotation; Figure 19, full supination.
Case 3. F. J., aged sixty-two years. Anterior Monteggia fracture with maximal displacement of the head of the radius in full pronation (Fig. 20). Full supination (Fig. 21), even with long axis-traction (Fig. 22), failed to achieve reduction, but with direct pressure on the head of the radius reduction was completed (Fig. 23). In three months, the longest period of immobilisation in this series, the ulna had united and the superior radio-ulnar joint was stable.

Case 6. J. G., aged seven years. Compound fracture of the ulna with anterior dislocation of the head of the radius. The upper fragment of the ulna penetrated the skin anteriorly, well away from the subcutaneous border. Figure 24 shows the position in full pronation and Figure 25 in mid-rotation. Figure 26 shows the reduction secured by full supination. Eight weeks later the fracture was united and the superior radio-ulnar joint was stable in all positions of rotation: Figure 27 shows that there was stability in full pronation.
Case 9. K. P., aged five years. A case of anterior dislocation of the head of the radius without fracture of the ulna (Fig. 28). Reduction was obtained by supination and immobilisation in plaster. Eight weeks later the reduction was stable in all positions of rotation (Fig. 29).

Case 10. B. W., aged ten years. Severe pronation injury of the right elbow. Anterior dislocation of the upper end of the radius with separation of the capital epiphysis (Figs. 30 and 31). At operation, the superior radio-ulnar dislocation could be reduced only in full supination (Fig. 32).
Several points may be emphasized:

1) In nine of the eleven cases reduction of the superior radio-ulnar dislocation was achieved by closed methods and direct pressure on the radial head was required only twice. When closed manipulation was successful, full supination was usually necessary to reduce the dislocation, but in one exceptional case reduction appeared to be more complete in mid-rotation and the limb was accordingly immobilised in this position.

2) Two patients were submitted to operation. In one case the fracture was two weeks old and closed reduction failed; in the other there was wide separation of the epiphysis of the radial head and operation was performed for its replacement. In both cases it was observed by direct vision that the superior radio-ulnar dislocation was reduced by full supination and recurred when the forearm was pronated.

3) At the end of treatment radiographs in three rotational positions showed that in ten cases the superior radio-ulnar joint was stable and in perfect position. In the one case in which late open reduction had been performed (Case 4), there was slight forward subluxation of the joint in all positions of rotation.

4) The fracture of the ulna united in all cases and the maximum period of immobilisation in plaster was twelve weeks.
In ten out of eleven patients the final range of elbow movement was approximately normal. In the case in which the radial epiphysis was replaced at operation (Case 10), the final range of rotation was much restricted. This case is particularly interesting because of the history. The patient was a boy aged ten years who caught the sleeve of his coat in the rollers of a machine. His forearm was pronated with such force that he was picked up and whirled round twice before falling to the ground.

CONCLUSIONS

1. Anterior dislocation of the head of the radius with or without fracture of the ulna is a forced pronation injury.
2. Full supination is essential for reduction, and immobilisation in full supination is the surest safeguard against recurrence of the deformity.

I wish to thank Mr C. C. Jeffery for his help in the preparation of this paper; Professor C. F. V. Snout of the Department of Anatomy, University of Birmingham, for his co-operation in the experimental work; and Mr Gill of the Photographic Department of the Birmingham Accident Hospital for the preparation of the illustrations.

REFERENCES


