Original Article
MONTEGGIA LESIONS IN CHILDREN AND ADULTS: AN ANALYSIS OF ETIOLOGY AND LONG-TERM RESULTS OF TREATMENT
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The good prognosis of Monteggia fractures in children is well known, provided the combined lesion is recognized. Excellent or very good results have been reported in 90% to 100% of cases.1-4 In contrast, Watson-Jones maintains that 95% of adults had sequelae after a Monteggia fracture.5 The mechanism of trauma causing Monteggia lesions has been much debated, and disagreement persists. Several theories regarding different types of Monteggia lesions have been proposed without taking into account the differences in the mechanism of trauma in pediatric and adult fractures. This study compares the mechanism of trauma and the final results of treatment in children and adults with Monteggia lesions.

MATERIALS AND METHODS
From 1975 to 1985, 33 patients with Monteggia lesions were treated. There were 17 children (11 boys, 6 girls) with an average age of 7.5 years (range, 3 to 15) and 16 adults (8 men, 8 women) with an average age of 43 years (range, 18 to 78). The results are based on a review of the case records and initial roentgenograms combined with follow-up examinations after an average of 7.5 years (range, 3 to 12). One patient died shortly after admission from a concomitant subdural hematoma and two patients could not be located, leaving a total of 30 patients to be examined.

Bado’s classification of Monteggia lesions into four types, primarily based on the location of the dislocated radial head, was used.6 In type 1 the radial head is dislocated anteriorly, in type 2 posteriorly, and in type 3 laterally. In type 4 the radial head is dislocated anteriorly, but is combined with a fracture of the radius as well as the ulna. In addition a fracture of the ulna combined with a fracture of the radial neck was considered a Monteggia equivalent lesion. An isolated dislocation of the radial head was also considered to be a Monteggia equivalent lesion. In children, such an apparently isolated dislocation of the radial head may be combined with a plastic deformity or a minimal greenstick fracture of the ulna (Fig 1).

All lesions were treated within 48 hours. At follow-up examination, the range of motion was classified as excellent, good, fair, or poor, according to Boyd and Beals.7 Pain in the elbow or forearm was described as none, slight (not significantly affecting the patient), moderate (influencing the patient’s daily activities), or severe (constant and significant). At the roentgenographic examination a standardized procedure was used to enable analysis of even small persistent subluxations and changes in curvature of the forearm bones. Both forearms of all patients, including the elbow and wrist joint, were examined in two perpendicular planes with fixed distances between film, arm, and x-ray tube. During this examination the forearm was held in an unchanged supinated position.

RESULTS
The mechanism of trauma and concomitant injury is shown in Tables 1 and 2. In children (Table 1) the source of trauma was most frequently a fall in which the child had tried to defend himself with the arm, or landed directly on top of it. However, the exact position of the

ABSTRACT
The mechanism of trauma and late results of treatment were analyzed in 17 pediatric and 16 adult Monteggia lesions. Pediatric Monteggia lesions were almost entirely found to be the result of low energy trauma leading to a closed, noncommittted fracture in an otherwise noninjured child. In the adult cases, however, these lesions were most often found to be the result of high energy trauma leading to open and committted fractures. Furthermore, 62% of the adults had other, and often more serious, injuries. Results at follow up (average 7 years) were excellent in the pediatric cases, whereas all adults had sequelae, especially regarding range of motion. The results of this study clearly suggest that a Monteggia lesion represents a more severe injury in the adult.
Fig 1: Monteggia equivalent lesion in a 7-year-old boy (case 15), consisting of anterior dislocation of the radial head and a plastic deformity of the ulna.

Arm at the moment of trauma could rarely be reconstructed. Most frequently the child fell from the same level. These traumas were low-energy, considering that only one child had an open fracture and only one had a concomitant injury (slight head injury) and a comminuted fracture. In the patient with the open fracture, there was a deep abrasion located at the fracture site of the ulna.

Most cases were type 1 lesions. The equivalent lesions included one case with an anterior dislocation of the radial head accompanied by a plastic deformity of the ulna (case 15), and two cases with fracture of the ulna combined with fracture of the radial neck (cases 16 and 17). In addition to the two cases where there were a plastic deformity and a comminuted fracture of the ulna, there were 11 oblique and four transverse fractures. A transient paralysis of the radial nerve was found in three cases. Nine of the lesions were located in the dominant arm. One case (case 2) was not recognized until the follow-up examination.

In adults (Table 2) seven fractures occurred from a fall, four from a blow, and six from a road accident. Three of the falls occurred from high levels. Ten patients had accompanying injuries, often several and severe. Six of the patients were multi-traumatized and one of these died due to subdural hematoma. Five patients had other fractures of the same extremity. Nine of the fractures were open, and in eight of these cases the wounds were located dorsally and clearly the result of a direct impact. Only in one case of an open fracture was this caused by perforation of the bone ends, resulting in a small puncture wound on the anterior aspect of the forearm. Ten fractures were comminuted and all type 2 and Monteggia equivalent lesions were accompanied by a fracture of the radial head or neck. The two equivalent lesions included one case of isolated dislocation of the radial head (case 33) and one case of fracture of the ulna combined with a fracture of the radial head and neck (case 32). Two cases of transient paralysis of the radial nerve were found. One of these occurred after open reduction of the radial head combined with resection and reconstruction of the annular ligament. Vascular damage (intimal tear of the brachial artery) was found in one case and immediately repaired. Nine of the lesions were located in the dominant arm.

In children, closed reduction was always attempted, and was successful in 14 cases (Table 1). In one child, the ulna fracture could not be reduced and was therefore stabilized with a Rush pin (case 6). One child had an open reduction of a fracture of the radial neck, which was part of an equivalent lesion (case 17). In a 3-year-old boy, the combined lesion was not recognized in spite of the fact that the ulna fracture necessitated a reduction under general anesthesia (case 2).

In adults, closed reduction of the combined lesion was successful in only four cases (Table 2). Osteosynthesis, using different implants, was performed in 10 cases. Four patients had an open reduction of the radial head. Two of these had a destroyed annular ligament resected and reconstructed with a fascial slip from the forearm. One patient had the radial head primarily excised because of a very comminuted fracture (case 32). Fixation of the radial head with a Kirschner wire drilled through the capitellum of the humerus was performed in one severely injured patient as a salvage procedure (case 21). One patient was reoperated because of a redislocation (case 28), and three patients were later reoperated because of a pseudoarthrosis (cases 20, 29, and 30).

In children, all fractures had healed at follow-up examination. Range of motion was excellent in 15 cases, and good in one case. None of the children had pain in the arm. Roentgenographically, four children were found to have an increased curvature of the ulna. This had clinical importance in only one case due to a slight restriction of supination. Four children had slight changes (about 5 degrees) in the carrying angle of the elbow, but this had no clinical significance. None of the children had persistent subluxation of the radial head. Soft tissue calcifications, or secondary osteoarthritis. At follow up, one case of an unrecognized 3-year-old type 1 Monteggia lesion was included (case 2). This child had a normal and free range of motion, no pain in the arm, and a normal carrying angle of the elbow, but the styloid process of the ulna was slightly more prominent than on the opposite side. The child felt no restriction in his
daily activity and participated in sports. Roentgenographically the radial head was still in the anterior dislocated position and had a dysplastic appearance as well as the capitellum of the humerus. It was decided to forego treatment. Case 13 could not be followed.

In adults, all fractures had healed at follow-up examination. Only one patient had a normal range of motion (considered excellent, case 28). In nine patients range of motion was good, in two fair, and in two poor. In five of these patients, range of motion was more or less limited by sequelae from other injuries of the same arm. Two patients had sequelae from a distal fracture of the humerus (cases 19 and 20), two patients had sequelae from severe soft tissue lacerations of the forearm (cases 22 and 30), and one patient sustained a total paralysis of the arm after a traumatic lesion of the brachial plexus (case 32). Six of the patients had no pain, four had slight pain, and four had moderate pain. Five patients had slight to severe osteoarthrosis of the elbow.

The patient who primarily had the radial head excised developed 15 degrees of valgus of the elbow, and because of "shortening" of the radius at the wrist joint a secondary osteoarthritis developed there as well (case 32). One case of persistent subluxation of the radial head was encountered, which primarily led to a restricted supination (case 22). Two cases of increased curvature of the ulna were encountered (cases 19 and 27). One of these is shown in Figure 2. At follow-up one patient had retired on disability and two had begun doing less heavy work. Two patients could not be followed (cases 21 and 31).

**DISCUSSION**

In 1814 the Italian surgeon Monteggia published, shortly before his death, two cases of fracture of the proximal ulnar shaft associated with an anterior dislocation of the radial head. It has later been established that a dislocation of the head of the radius can be anterior, posterior, or lateral, and accompanied by a fracture of the ulna at any level. In addition, a number of equivalent lesions with similar characteristics exist. In 1967 all of these lesions were classified by Bado as "Monteggia lesions." Bado's list of equivalent lesions is extensive; all of the lesions (especially the isolated fracture of the radial neck and certain fractures of both forearm bones) cannot reasonably be considered Monteggia equivalent lesions.

Theories regarding etiology of Monteggia lesions have been much debated, especially concerning type 1 lesions. In the older literature the mechanism of injury was almost always thought to be the result of application of direct force, for instance, a fall on the posterior aspect of the forearm or an object hitting the arm of a patient trying to parry a blow. In 1949 Evans put forward his hyperpronation theory, which
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RA = Road accident
E = Monteggia equivalent lesion
§ = Both ulna and radius fracture
§§ = No ulna fracture

later was supported by Bado. According to this theory the fracture is caused by a fall on the outstretched and hyperpronated arm. In support of this view it was emphasized that these lesions almost never were open. This theory was later contradicted by Tompkins, who claimed that a fall on the outstretched arm would lead to a violent reflex contraction of the biceps, resulting in a dislocation of the radial head anteriorly. When this occurs, all weight is borne by the ulna and, as a result of the longitudinal compressive force, coupled with the pull of the intact interosseous membrane and the simultaneously contracting brachialis, the ulna fractures and angulates anteriorly.

We find it difficult to believe that a unique and well-defined mechanism of trauma could be responsible in individual Monteggia lesions, especially when no distinct is made between pediatric and adult cases. These lesions may be the result of a direct as well as an indirect force. The latter may very well be the result of hyperpronation or the above-mentioned mechanism described by Tompkins. A comparison of pediatric and adult cases, however, shows a certain pattern. A survey of the literature shows that in children 90% to 100% of the cases were caused by a fall (usually from the same level), and only a minority had compound fractures. Where the localization of the wounds were described, they were most often found on the anterior aspect of the forearm and caused by perforation of the fractured ulna from the inside.

This study further emphasizes the low-energy character in the pediatric cases by the fact that only one child had a concomitant injury. In the adult cases the mechanism of trauma was more varied, but often of high-energy nature emphasized by the facts that 62% had concomitant injuries and/or a comminuted fracture and that 56% had an open fracture. Corresponding figures are only given in few papers, but Jessing and Barquet and Caresani found 30% and 50% of the adults, respectively, severely injured. In this study most compound fractures were the result of a direct force acting on the forearm from the outside. One case, however, was obviously the result of perforation from the inside. This, as well as the fact that a few adult fractures were caused by low energy, suggests several possible mechanisms in individual cases. The results of this study, however, suggest that a Monteggia lesion often represents a more severe injury in the adult. Although Bado's classification is excellent in describing the main characteristics of a Monteggia lesion, it does not imply anything about the origin.

Results at follow up confirm the good prognosis in children that can be achieved after
closed reduction in the majority of cases. Cases with an oblique fracture of the ulna may be unstable, which led Fowles et al to recommend intramedullary nailing in these cases. Most of the pediatric fractures in this study were oblique, and like other authors we encountered no problems after closed reduction. A child with an unrecognized 3-year-old Monteggia lesion was left without treatment at follow up in this study. These cases, especially those without any symptoms, still represent an unsolved problem. Several authors have reported good results after open reduction of the radial head, reconstruction of the annular ligament, and a corrective osteotomy of the ulna, but in none of the reported cases had 3 years elapsed from fracture to operation. After such a period, disturbances of growth will be found in the capitellum of the humerus and the radial head, and the best treatment is probably to leave the radial head in the dislocated position. Stelling and Cote reported good but not perfect results after conservative treatment. Excision of the radial head should not be considered until the patient is fully grown.

In this present study a large proportion of the adult fractures were treated with Rush pinning or closed reduction (nine cases), three of which developed a pseudoarthrosis leading to secondary operations. In adult Monteggia fractures restoration of length and curve is necessary. Furthermore, healing of adult forearm fractures is relatively slow, probably because of the small contact surfaces of the fractured fragments. For these reasons anatomical reduction and stable fixation is essential, and in the more recent cases encountered in this study, open reduction and plating were used. The advantage of this method compared with conservative treatment or Rush pinning has been documented by Hertel and Schweiberer. The dislocation of the radial head can generally be reduced without opening the joint. There is an indication to open the joint if closed reduction can not be achieved or if fracture of the radial head necessitates excision or internal fixation. If the annular ligament is damaged a simple suture may be all that is needed, but when there is considerable damage, resection and a reconstruction is necessary.

In the present study a fascial slip from the forearm was used, as described by Boyd and Boals. A slip from the triceps tendon may be used to reconstruct the annular ligament. In terms of range of motion the results in this material were inferior to the results of Hertel and Schweiberer (mainly plating), but corresponded well with the results of Boyd and Boals (mainly Rush pinning). As pointed out earlier, concomitant injuries affected range of motion in a great proportion of the cases in this material, and since data concerning this were not given in the above mentioned articles, a fair comparison of results of treatment is difficult.

Finally, it should be noted that the standardized roentgenographic procedure used in this follow up gives a "high number" of abnormal findings, since it is able to disclose even small persistent dislocations of the radial
head and changes in curvature of the forearm bones, which otherwise would be difficult to quantitate. The method is also useful in other situations. For example, it has proven valuable in planning corrective osteotomies of the forearm bones after lesions other than Monteggia fractures.

CONCLUSION

Monteggia lesions in children are usually the result of low-energy trauma, and consequently comminuted and open fractures and concomitant injuries are rarely encountered. In contrast, adult Monteggia lesions often are the result of high energy trauma, resulting in high numbers of open and comminuted fractures. A high proportion of the adults have other and severe injuries. In children, closed reduction of the combined lesion should always be attempted and usually gives excellent results. In adults, anatomic reduction and a stable fixation (plate) is recommended. The radial head generally can be reduced without opening the joint. If an open reduction is carried out, suture or reconstruction of the annular ligament should be done as needed. In this study, range of motion was affected in a great proportion of the cases by other and concomitant injuries of the same extremity. This is probably an underestimated observation, which makes comparison of other treatment results difficult.

REFERENCES