CURRENT CONCEPTS IN THE TREATMENT OF RADIAL HEAD FRACTURES IN THE ADULT A CLINICAL AND BIOMECHANICAL APPROACH

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The treatment of simple radial head fractures type Mason-Hotchkiss 1 and 2 is unequivocal. In the case of a displacement of less than 2 mm (Mason-Hotchkiss 1), functional conservative treatment is indicated. If the displacement is more than 2 mm (Mason-Hotchkiss 2) internal fixation is indicated, combined with treatment of the soft-tissue injuries.

The treatment of comminuted radial head fractures Mason-Hotchkiss type 3 is more controversial, as they are usually associated with ligament injuries. Conservative treatment appears to have unsatisfactory results. Opinions differ on surgical treatment, i.e. 1) excision of the radial head ; 2) reconstruction by means of internal fixation ; 3) excision and reconstruction with a prosthesis. Basic experimental research on human cadaver elbows shows the importance of the conservation of the radial head, especially in case of associated soft tissue injuries. In most cases a stable osteosynthesis is impossible, and in case of associated ligament disruptions, resection and reconstruction by means of a rigid radial head prosthesis should be considered. Experimental research demonstrates promising results for rigid radial head prostheses in human cadaver elbows with a resected radial head and failing medial collateral ligament. Short-term clinical studies seem to confirm this, but long-term results are as yet unknown.

Keywords : radial head ; fracture ; osteosynthesis ; prosthesis.

Mots-clés : tête radiale ; fracture ; ostéosynthèse ; prothèse.

INTRODUCTION

Since Lambotte (53) carried out the first osteosynthesis for a radial head fracture in 1909, the treatment of this fracture has been controversial. Charnley (14) and Boehler (10) recommended functional, conservative treatment ; resection was only indicated in case of limited pronation and supination.

H. Judet (42), Key and Conwell (44) and Smith (78) carried out radial head resections in case of comminuted fractures in order to prevent ankylosis and functional impairment.

Speed (81), Edwards and Rostrup (18), Cherry (15) and Carr and Howard (13) implanted a metal (13, 81) or acrylic (15, 18) radial head prosthesis to avoid proximal radius migration and associated wrist disorders after radial head resection for comminuted radial head fractures. Robert Soeur (79) on the other hand prevented this by pinning the radius to the ulna.

Watson-Jones (88) surgically explored most comminuted radial head fractures, because standard radiography does not easily reveal underlying associated lesions, e.g. medial band lesions and fissures in the capitellum.

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Mason (55) was the first to systematize the treatment on the basis of a radiological classification, which is known today as the Mason classification. He distinguished three groups : type 1 fractures, with little or no displacement, treated conservatively with good results ; type 2 fractures, with displacement, usually treated conservatively and sometimes treated by resection because of marked displacement and type 3 fractures, comminuted and requiring resection.

Most controversies concern the treatment of displaced and comminuted radial head fractures, where reconstructions (12, 22, 25, 32, 43, 46, 52, 60, 68, 77) and resections (16, 39, 65, 71) are balanced.

BIOMECHANICS

In order to gain a clearer understanding of the consequences of radial head resections (1, 18, 32, 59, 71, 84) (elbow instability, radiocapitellar joint contact loss, proximal migration of the radius) in comminuted radial head fractures, research was carried out on human cadaver elbows in order to examine the function of the radial head (31, 51, 63, 64, 66) and the role of the anterior band of the medial collateral ligament (aMCL), the interosseous membrane (MI) and the triangular fibrocartilaginous complex (TFCC) (20, 37, 38, 66, 70, 74, 75).

Basic experimental research showed that 60% of an axial load at the elbow is transmitted through the radiocapitellar (RC) joint (3, 31, 64), especially in pronation between 0° and 30° flexion (65).

In a next stage, Morrey and An (63) and Schwab *et al.* (73) demonstrated the important role of the aMCL in resisting valgus forces on the elbow in 90° flexion. In extension however, the role of the anterior capsule, the bony contours of the joint and the medial collateral ligament appeared to be equivalent. Morrey and An (66) and Hotchkiss (38) pointed out that the aMCL is the primary stabilizer resisting valgus stresses, and that the radial head takes over this function in case of a failing aMCL ligament.

The influence of the MI and the TFCC on proximal radius migration after resection of the radial head was the subject of an experimental study by Hotchkiss *et al.* (37). They found a thickened central zone in the membrane, which is responsible for 71% of the axial stability after resection of the radial head. The TFCC appeared to account for only 8%. The authors concluded that lesions of this central band are responsible for proximal radius migration after resection of the radial head. They warn against radial head resection in case of comminuted fractures. Engel *et al.* (20) came to the same conclusion after research on cadaver elbows with dynamic magnetic resonance imaging (MRI). They found an enlarged radio-ulnar distance in pronation and supination in case of experimentally caused lesions of the membrane, compared to normal forearms. They proposed MRI examination for all patients with a Mason 3 fracture, in order to detect lesions of the interosseous membrane.

Rigid radial head prostheses (metal, ceramic, ultra-high molecular weight polyethylene) give better load transfers at the RC joint than silicone radial head prostheses (12, 29, 38, 51, 52). Moreover, silicone implants are not only unable to resist axial forces without showing deformations (12, 29, 52), they are also incapable of providing valgus stability in MCL deficient elbows (51) .

On the other hand, there is a potential danger of stress-shielding (29), overstuffing (29, 77), altered load transfers (29), induction of cartilage lesions on the capitellum (29, 38, 51, 77) and osteoarthritic changes (12) when rigid radial head prostheses are used. A number of these complications may result from incorrect length and orientation in reconstruction of the radial head (12, 51, 77), and further experimental research is necessary to assess the importance of these factors.

It can be concluded that the radial head as well as different ligamentous structures are extremely important for normal functioning of the elbow (17, 22, 29, 37, 38, 51, 61, 62, 63, 66, 89).

DIAGNOSIS

1 : Radial head fractures : Clinically there is pressure pain, loss of function and swelling. Standard radiographic examination shows the radial head fractures and possible associated fractures

(73, 74). Greenspan (28) stresses the importance of the radial head-capitellum view for better evaluation of the radial head. CT can give additional information on the size and the displacement of the fragments (36). In case of comminuted and displaced fractures, the distal radioulnar joint must be examined clinically (19, 61) as well as radiologically (17, 19).

2 : Soft tissue lesions : Clinically one can observe medial ecchymosis (17, 41), medial elbow pain (17, 41), pressure pain at the wrist (17) and swelling of the forearm (17). In a clinical prospective study of 50 patients, Davidson *et al.* (17) demonstrated the importance of the fracture morphology of the radial head and associated ligamentous injuries of forearm and wrist. The authors described a valgus stress test to detect MCL lesions and an axial stress test to look for MI injuries. Fractures with minimal displacement (less than 2 mm) were all stable. Impacted or displaced fractures (displacement more than 2 mm) showed more or less valgus instability. Comminuted fractures all showed axial or valgus instability, an observation confirmed by King (46), who always suspects ligamentous injuries associated with this kind of fractures.

Hill (34) pointed out the accuracy of MRI examination in experimentally caused MCL lesions in cadaver elbows, and in a similar study lesions of the interosseous membrane were demonstrated with MRI (20).

CLASSIFICATION

The Mason (55) classification is the most widespread. It is based only on the radiological findings of the radial head fracture but it does not take into account any associated lesions. A type 1 fracture shows little or no displacement. A type 2 fracture is displaced. A type 3 fracture is comminuted. A radial head fracture combined with a dislocation is a Mason type 4.

Some authors (3, 7, 17, 22, 36, 46, 61, 62) point out the importance of associated soft tissue and bony injuries that should be taken into account in a classification system. Hotchkiss (36) therefore developed a practical classification (table I) based on Mason's findings with radial head fractures.

MECHANISM

A fall on the outstretched hand in pronation with slight elbow flexion is the classical cause of a radial head fracture (62). Amis (3, 4) confirmed this mechanism by creating fractures *in vitro* in cadaver elbows in a controlled experiment by means of a "purpose-built impact loading rig". The pattern of the fractures corresponds to the clinical findings as described by Mason. Twelve radial head fractures were caused by an indirect impact between 0° and 80° flexion. Eight of them were associated with a posterior dislocation. In his conclusion Amis points out the importance of soft tissue injuries and associated instability in case of radial head fractures.

In their prospective study, Davidson *et al.* (17) found that 72% of patients with comminuted radial head fractures sustained a fall on the outstretched hand. A direct blow on the elbow was responsible for 67% of the minimally displaced fractures.

Table I. — Mason-Hotchkiss classification for radial head fractures

1.	Uncomplicated radial head fracture without associated lesions.
1.1	Mason-Hotchkiss 1 : displacement < 2 mm
1.2	Mason-Hotchkiss 2 : displacement > 2 mm : reconstruction possible
1.3	Mason-Hotchkiss 3 : comminuted fracture : reconstruction impossible
2.	Complicated radial head fracture associated with dislocation, other fractures and ligamentous lesions.
2.1	Mason-Hotchkiss 1 : displacement < 2 mm
2.2	Mason-Hotchkiss 2 : displacement > 2 mm : reconstruction possible
2.3	Mason-Hotchkiss 3 : comminuted fracture : reconstruction impossible.

TREATMENT

Treatment of radial head fractures will be discussed according to the Mason-Hotchkiss classification, and finally the handling of the associated injuries will be outlined.

Mason-Hotchkiss type 1

In case of minimal fracture displacement most authors agree on a conservative functional treatment by means of sedation (76), exercise therapy (1, 13, 25, 41, 71, 76, 90), aspiration (1, 13, 21, 90), and immobilization with (56, 71, 79) or without (76) a plaster cast. The fracture treatment does not change with associated soft tissue injuries, which are rarely addressed (41, 56, 90). Wesely (90) over a period of 20 years treated 329 type 1 fractures conservatively with good results and minimal complications.

Mason-Hotchkiss type 2

Treatment

In case of displaced fractures (fig. 1) a stable reconstruction by means of internal fixation is a prerequisite (fig. 2) to allow immediate mobilization and preven stiffness of the elbow joint (22, 45, 47, 53, 76). This can be achieved by the use of small fragment screws (22, 24, 45, 76), Herbert screws (22, 45, 58), plate and screws (22, 24), and resorbable polyglycolid pins (35). Few authors prefer a resection to a reconstruction (16, 71, 82).

Results

The results after internal fixation are good with regard to pain (24, 76), mobility (22, 24, 76), strength (24, 76) and degenerative disease (76). From a comparative study of 26 patients with Mason type 2 fractures, with a follow-up of 18 months, Khalfayan *et al.* (45) concluded that displaced radial head fractures treated conservatively had more pain and loss of strength and were less mobile than fractures treated by a stable osteosynthesis.

Stephen (82) reports on the clinically acceptable results of 12 patients with radial head resections for seriously displaced fractures, with a follow-up of 23 years. The author draws attention to the danger of radial head resection in case of fracture dislocation, and states that a prosthesis is better in this setting.

Fig. 1. — Preoperative lateral xray of a Mason-Hotchkiss type 2 radial head fracture.

Radin and Riseborough (71) examined 88 patients with radial head fractures, of whom 25 had a type 2 fracture. The treatment was functional if the displaced fragment was smaller than two thirds of the radial head, whereas the head was excised if the fragment was larger than two thirds. The results were acceptable but not optimal.

Mason-Hotchkiss type 3

Treatment

This type of fracture (fig. 3) is associated with capsular or ligamentous disruptions (17, 41) causing proximal migration (59, 71, 84), cubitus valgus

Fig. 2. — Postoperative anteroposterior and lateral xray after treatment with a minifragment screw osteosynthesis of the radial head.

Fig. 3. — Preoperative anteroposterior xray of a Mason-Hotchkiss type 3 radial head fracture with elbow dislocation before and after reduction.


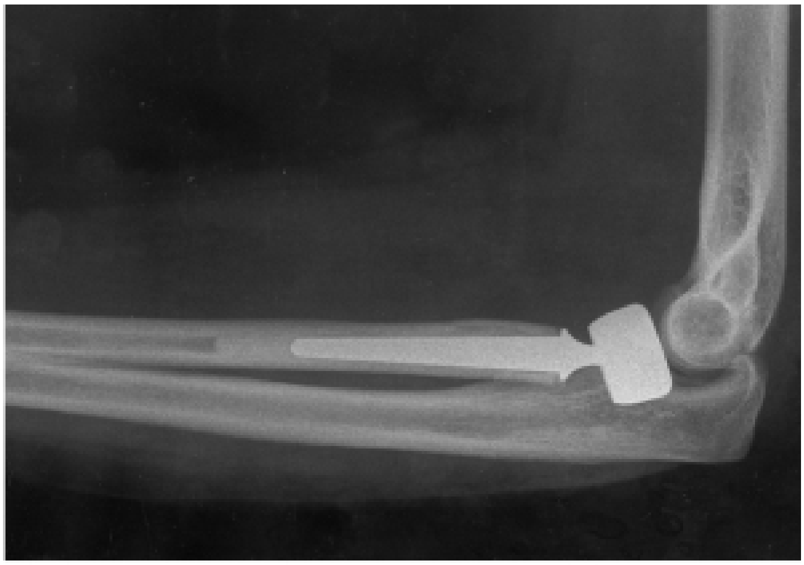

Fig. 4. — Postoperative anteroposterior and lateral xray after treatment with a floating radial head prosthesis.

(59, 84), ulnar nerve neuritis (84), instability (32, 84), wrist problems (59), or altered elbow kinematics (32, 40, 59) after radial head resection. This treatment is still considered as standard in cases of comminuted fractures (16, 39, 65, 71). Other authors consider it essential to reconstruct the radial head by means of osteosynthesis (22) or to replace it with a prosthesis (12, 22, 25, 32, 43, 46, 52, 60, 68, 77).

Silicone prostheses (12, 22, 54, 84, 86) are less used today because they cannot transmit loads as a rigid radial head (12, 29, 32, 51, 52), and because complications such as broken prostheses (9, 11, 57, 65, 87) and inflammatory synovitis (9, 27, 85, 87) have been described. At the moment metal (13, 32, 43, 52, 60, 68, 77, 81) implants are used, of which the bipolar cemented T. Judet radial head prosthesis (fig. 4) is best known (43, 68, 77). Acrylic prostheses (15, 18) have also been implanted, in analogy with the acrylic hip prosthesis developed by J. Judet, but have been discontinued.

Results

Frankle (22) treated 21 patients with an elbow dislocation, including 17 with a comminuted radial head fracture. Nine of them were treated by osteosynthesis, and 8 had a silicone prosthesis, with an average Mayo score of 77.5/100.

In a retrospective study of 17 patients with Mason type 2 and 3 radial head fractures, who were treated by resection of the radial head and who had a follow-up of 8 to 46 years, Coleman (16) showed reasonable results. Six of the patients had rest pain or pain during motion, type 3 fractures showed more degenerative ulnohumeral disorders, the valgus was on average 20° on the resected side and 10° on the normal side, and valgus angulation was seen more frequently in case of Mason type 3 fractures. The ulnar variance increased by an average of 2 mm.

In a study of 21 patients with a follow-up of 16 to 30 years after radial head resection for comminuted radial head fractures, Janssen *et al.* (39) found 17 excellent, 3 good and 1 fair clinical results according to the functional rating index of the Mayo Clinic. The radiological evaluation showed proximal migration of the radius between 1 and 3 mm in 12 patients, and mild degenerative changes in 11 patients. The authors concluded that early radial head resection is a valid option for uncomplicated type 3 fractures.

Mikic' *et al.* (59) on the other hand reported on 60 patients after radial head resection for isolated radial head fractures with a follow-up of 1 to 12 years. They found that 43% of the patients were symptomatic, 52% suffered from osteoarthritis, 63% had a decreased range of motion, 58% had decreased forearm rotation, 47% showed proximal migration, and overall poor results were seen in 50% of the patients. On the basis of these data, the authors state that resections should be restricted, and that reconstructions should be considered.

Harrington and Tountas (32) treated 17 fracture-dislocations of the elbow with associated radial head fracture with resection and reconstruction by means of a metal radial head prosthesis, with a mean follow-up of 6.9 years. They registered 14 good results (maximum 20% loss in range of motion, slight loss of strength, no discomfort) ; 2 patients showed a painful 50% loss of range of motion and loss of strength. One patient had severe pain, and although motion and xrays were normal, the prosthesis was removed and the pain subsided.

A comparative retrospective study conducted by Stoffelen and Holdsworth (83) on 39 patients with a radial head resection for comminuted radial head fractures, with 6.1 years follow-up, and 16 patients with a silicone radial head prosthesis after resection for comminuted radial head fractures, with 5.7 years follow-up, showed 55% good results after excision, versus 13% good results after implantation of a silicone prosthesis.

Berger *et al.* (9) on the other hand noted better results for patients who had a silicone radial head prosthesis implantation, than for patients who had a radial head excision for a comminuted radial head fracture, with a follow-up of five years. These authors however warn of silicone complications.

In a prospective study of 11 patients treated with a bipolar Judet radial head prosthesis for Mason type 3 fracture dislocations, with a follow-up of 2 years, Popovic *et al.* (68) registered 8 excellent and good, 2 fair and 1 poor result, according to the Mayo elbow performance index. The same result was reported in our own study (77) on 13 patients with Mason type 3 fractures with an average follow-up of 2 years : 10 excellent and good, 1 fair and 2 poor results according to the Mayo elbow score for acutely treated fractures.

Treatment of associated lesions

Radial head fractures and lateral collateral ligament disruptions are reconstructed at the same time (7, 22, 67, 72) ; in case of remaining valgus instability a restoration of the medial collateral ligament (6, 16, 67, 72) should be considered, which some authors never (32, 61) and others always (33) perform.

According to Regan-Morrey (61), coronoid fractures can be classified as 3 types : type 1 is a fracture of the tip of the coronoid, which can be treated conservatively ; in type 2 about 50% of the coronoid is avulsed and has to be fixed in case of remaining instability ; type 3 fractures involve more than 50% of the coronoid and must be fixed (61, 67, 72). If fixation is impossible, a hinged fixator should be considered (61, 72).

Olecranon fractures must be treated by internal fixation (61, 67, 72).

A radial head fracture associated with an elbow dislocation and a coronoid fracture is called a “terrible triad”. The radial head fracture has to be either reconstructed by internal fixation or replaced by a rigid prosthesis ; the coronoid fracture is treated according to the size of the fragment. If instability remains and in case of valgus stress instability, the medial collateral ligament has to be restored (7, 72). If there is still instability after fixing the radial head, coronoid and ligamentous structures, a hinged distractor is used (61, 72) .

A radial head fracture associated with acute proximal radius migration and disruption of the distal radioulnar joint requires stable restoration of the radial head (19, 36, 61) (osteosynthesis or rigid radial head prosthesis). The distal radioulnar joint can be pinned and put in a cast (19, 61), although this treatment is questioned (80).

DISCUSSION

Biomechanical and kinematic studies have demonstrated the important role of the radial head and of the soft tissues in the proper functioning of the elbow joint (6, 17, 22, 29, 37, 38, 48, 51, 61, 62, 63, 66, 89). Experimental research conducted on human cadaver elbows has shown that, unlike silicone radial head prostheses, metal and plastic radial head implants can assure axial and valgus stability (12, 29, 32, 51, 52). The mechanism that causes a radial head fracture and rupture of the surrounding soft tissues was simulated *in vitro* (3, 4, 17, 62, 67).

The modified Mason-Hotchkiss classification (36) is simple, and can be used in a clinical setting to outline the fracture treatment as well as for study objectives, to define the associated lesions (7, 17, 22, 36, 61, 62).

The diagnosis is made on the basis of a clinical and a conventional radiological examination of the elbow (28) and wrist (17, 19). A CT-scan (36) and MRI (20, 34) can give more information regarding fracture displacement, comminution and soft-tissue injury. An intraoperative axial and valgus stress test can demonstrate axial or valgus instability or confirm soft-tissue lesions suggested by CT or MRI.

Stable reconstruction of all the fractures and associated soft-tissue injuries near the elbow joint is a prerequisite to start immediate postoperative physiotherapy and motion exercise in order to avoid stiffening (22, 45, 47, 53, 72, 76). Poor results are directly related to immobilization periods longer than 3 to 4 weeks (61).

In the literature varying clinical results are reported regarding radial head resections (9, 16, 23, 26, 39, 59, 83). Clinical (32, 40, 59, 71, 80, 84) and experimental studies (2, 12, 20, 37, 51, 63, 66) have demonstrated associated complications after radial head resections, such as proximal migration of the radius, elbow instability, wrist problems and altered elbow kinematics.

As Mason-Hotchkiss type 3 injuries or comminuted radial head fractures are accompanied by soft-tissue lesions (17, 41) reconstruction by means of a stable osteosynthesis (22) or, if this is impossible, a prosthesis (12, 22, 25, 32, 43, 46, 52, 60, 68, 77) of the radial head is preferred to resection. Experimental studies (12, 29, 51, 52) as well as short-term clinical results (32, 43, 51, 52, 68, 77) are promising and demonstrate a preference for more rigid substitutes than silicone radial head implants. In order to show the advantages of prosthetic radial head surgery over radial head resections in case of radial head type 3 fractures more clinical prospective long-term trials are required using a standardized method to assess elbow function (49).

Furthermore, anthropometric studies of the radial head and neck have shown great variability between individuals, and it is therefore difficult to reconstruct with an implant the exact anatomical radial head dimensions (8, 30, 50). The consequences of lengthening, shortening, axial deviation and orientation of radial head implants on the radiocapitellar joint and on the elbow biomechanics are unknown, although these alterations could cause a change in articular contact surface and induce peak stresses on the cartilage, resulting in degenerative disorders (5, 68). Therefore, further basic biomechanical research is necessary to determine the consequences of such alterations and to define which of those can be accepted in order to make new designs and adjust the existing instrumention to implant a radial head prosthesis correctly.

In our department the following scheme is used to handle radial head fractures in the adult :

	Associated lesions	No associated lesions
Mason-Hotchkiss 1	Functional	Functional
Mason-Hotchkiss 2	ORIF	ORIF
Mason-Hotchkiss 3	Prosthesis	Prosthesis or resection

1) Associated fractures should be treated according to current concepts.

2) Soft tissues are treated if there is remaining instability after fracture reconstruction.
3) Finally, if the elbow joint is still unstable, a hinged distraction external fixator as described by Morrey (61) is used.

CONCLUSION

1) An intact radial head as well as intact ligamentous structures are essential for good elbow function.
2) In case of a radial head fracture, reconstruction is preferred to resection.
3) More basic research on radial head biomechanics is needed, particularly the repercussions of altered radial head dimensions on elbow joint function.
4) More clinical prospective pilot studies are required to assess the value of radial head reconstruction with an implant.

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SAMENVATTING

F. VAN GLABBEEK, R. VAN RIET, J. VERSTREKEN. De behandeling van radiuskop fracturen bij de volwassene. Een klinisch en biomechanisch standpunt.

De behandeling van eenvoudige radiuskop fracturen Mason-Hotchkiss type 1 & 2 is eenduidig. Indien een trapvorming bestaat kleiner als 2 mm is een functioneel conservatief beleid aangewezen bij de zogenaamde Mason-Hotchkiss 1. Bij trapvorming groter dan 2 mm is een osteosynthese aangewezen onafgezien van weke delen letsels bij Mason-Hotchkiss 2 fracturen.

Daartegenover is de behandeling van communitieve radiuskop fracturen Mason-Hotchkiss type 3 omstreden te meer dat deze meestal gepaard gaan met ligamentaire letsels. Een conservatief beleid geeft onvoldoende resultaten. De meningen verschillen over de heelkundige behandeling m.n. 1) excisie van de radiuskop, 2) reconstructie dmv osteosynthese, 3) excisie en reconstructie dmv een prothese. Basis experimenteel onderzoek op humane kadaver ellebogen toont het belang van het behoud van de radiuskop aan zeker bij geassocieerde weke delen letsels. In de meeste gevallen is een stabiele osteosynthese niet mogelijk en bij geassocieerde ligamentaire letsels moet een resectie en reconstructie door middel van een rigiede radiuskop prothese worden overwogen. Het experimenteel onderzoek toont veelbelovende resultaten naar de functie van de rigiede radiuskop prothese bij humane kadaver ellebogen met gereseceerde radiuskop en falend mediaal collateraal band apparaat. Klinische studies op korte termijn bevestigen dit doch de lange termijn resultaten zijn momenteel niet gekend.

RÉSUMÉ

F. VAN GLABBEEK, R. VAN RIET, J. VERSTREKEN. Le traitement des fractures de la tête radiale chez l'adulte. Mise au point clinique et biomécanique.

Le traitement des fractures simples de la tête radiale de type Mason-Hotchkiss 1 et 2 est univoque. Une fracture simple à déplacement minime (moins de 2 mm) de type Mason-Hotchkiss 1 est traitée de manière fonctionnelle. Si le décalage intra-articulaire est de plus de 2 mm (type Mason-Hotchkiss 2), une ostéosynthèse est à envisager pour permettre une mobilisation post-opératoire immédiate.

Comme le traitement conservateur d'une fracture comminutive de la tête radiale de type Mason-Hotchkiss 3 donne des résultats médiocres, un traitement chirurgical s'impose, pour lequel on dispose de trois options qui sont fortement discutées : 1) excision de la tête radiale, 2) reconstruction par ostéosynthèse, 3) excision et reconstruction par prothèse. Des études biomécaniques du coude humain démontrent qu'il est important de conserver la tête radiale, surtout s'il y a des lésions ligamentaires associées, ce qui est fréquent dans les fractures comminutives de la tête radiale. Une ostéosynthèse est souvent très difficile et il est impossible d'obtenir une reconstruction stable. La reconstruction par une prothèse rigide de la tête radiale est stable et des études biomécaniques ont montré des résultats satisfaisants. Les résultats cliniques à court terme sont prometteurs ; les résultats à long terme devront le confirmer.