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ORIGINAL STUDY

Multi slice computed tomography approach in the assessment of supracondylar humeral fractures in children

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The purpose of this study was to assess the impact of Multi Slice Computed Tomography (MSCT) on the understanding of the spatial displacement of supracondylar humeral (SCH) fractures, their classification and their management.

A prospective study was conducted on 63 children with SCH fractures Gartland II or Lagrange 2 and 3, over a period of 30 months.

The patients were 42 boys and 21 girls, aged between 3 and 14. All patients were imaged using conventional radiography. Thirty-two patients underwent MSCT and 3-dimensional reconstructions.

According to the Lagrange classification system, 16 patients had type 2 fractures and 47 had type 3 fractures. In type 2, the posterior cortices of both medial and lateral columns were bent on CT (n = 6). In type 3, CT-scan made it possible to distinguish two subgroups. In the first subgroup (n = 12) there was fracture of both anterior and posterior cortices of the lateral column ; however, the posterior cortical surface of the medial column was preserved. In the second subgroup (n = 14), there was no cortical surface contact in the medial column, but the continuity of the posterior cortical surface of the lateral column was preserved.

Based on a new concept of column stability, the use of CT-scan has allowed for a better understanding of supracondylar fractures in children.

Keywords : supracondylar humeral fracture ; children ; classification ; multi slice computed tomography.

INTRODUCTION

Supracondylar humeral (SCH) fractures are relatively common in children, accounting for at least 18% of all fractures in children and 75% of all elbow fractures (*3,6,17*). They mostly occur in children during the first decade of life (most commonly between 5 and 7 years), and they are more

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This study was carried out in the departments of Paediatric Radiology and Paediatric Orthopaedics, in Tunis Children Hospital (Tunis – Tunisia) with collaboration of "Unité de Recherche UR04SP11 – Pathologie du développement de l'os chez l'enfant".

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Table I. — Lagrange's classification of supracondylar fractures of the humerus in children

Type	Radiologic characteristics
1	Undisplaced fractures
2	Unidirectional displacement
3	Multidirectional displacement including posterior tilt, translation, rotation and coronal angulation. Contact between bone fragments is maintained
4	Fracture with complete displacement without contact between the fragments

Table II. — Gartland's classification of supracondylar fractures of the humerus in children

Type	Radiologic characteristics
I	Undisplaced fractures
II	Displaced fracture with intact posterior hinge
III	Completely displaced fractures with no contact between the fragments

common in boys (*4,16*). The typical mechanism is a fall on an outstretched hand that puts a hyperextension load on the arm. The distal fragment displaces posteriorly in over 95% of the cases (*2,19*). These fractures are classified using various classification systems according to both the direction and the degree of displacement of the distal fragment on radiographs (*2,4,23*). Two classifications are widely used. The Lagrange classification system is the most widely used in the French literature dividing these fractures into four types on the basis of antero-posterior and lateral radiographs (Table I) (*1, 13,15*). In the English literature, Gartland's staging system, based on the lateral radiograph, is most commonly used and fractures are classified according to a simple three-type system (Table II) (*2,8, 20,21*).

What are the differences between these classifications ? Why does Gartland classify fractures into only three types while Lagrange classifies them in 4 types ? According to numerous authors (*12,14*), there is no difference between Lagrange type 1 and Gartland type I ; in each case the fracture is incomplete and stable without displacement. Similarly, Lagrange type 4 and Gartland type III are identical, and in each case the fracture is unstable with no contact between the fracture ends. On the other hand, partially unstable fractures are classified in the Lagrange system as types 2 and 3 but they are classified as type II by Gartland system. Misunderstanding and failure to identify the exact bony lesions and consequent spatial displacement of the epiphyseal fragment, would be the origin of the differences between the two classifications and their non-optimal reliability.

As computed tomography (CT) has revolutionized our understanding of fractures and its usefulness and application in their configuration have been well established and proved to be particularly helpful in their management, we thought of exploring these fractures (Lagrange's types 2 and 3 and Gardland's type II) by CT-scan.

With this conviction that CT imaging is superior to plain radiographs to assess the fracture configuration, the purposes of our study were to identify and describe specific fracture patterns in moderately displaced SCH fractures previously unquantified, to understand the consequent 3-D displacement and to assess the impact of these CT findings on the management of these fractures.

PATIENTS AND METHODS

Definition

We defined a humeral supracondylar fracture as a simple and often transverse extra-articular fracture occurring within the distal metaphysis of the humerus, involving the medial and lateral columns.

Population

In the absence of a local Institution Ethics Committee, the staffs of our two departments of radiology and orthopaedics and the medical committee approved this prospective study. After explanation of the orthopaedic problem and the objective of the study, the parents of each patient had given us their consent before the patient was selected for CT examination.

We prospectively reviewed consecutive patients with SCH fractures referred to our institution during a period of 30 months, between November 2007 and April 2010. The patients selected were identified as Lagrange types 2 and 3, or Gartland type II, with an age below 16. Patients having Gartland type I and III fractures (Lagrange type 1 and 4) were excluded from the study. As previously mentioned, these types do not raise problems of classification or comprehension.

All patients were imaged using conventional radiography with antero-posterior (AP) and lateral projection of the injured elbow, sometimes completed by oblique views. CT was performed when the plain radiographs were not clear enough to understand the displacement and to allow planning for the management of the injury. It was discussed case by case by paediatric orthopaedic surgeons and paediatric radiologists in order to study the child's benefit at the expense of an acceptable irradiation. The mean time between CT scan and plain radiographs was 10 hours (range : 2 to 12 hours).

CT examination

All CT images were performed using a standard protocol with a 6-slice CT scanner (SOMATOM EMOTION 6, Siemens Medical System, Germany). Collimation and table feed were 6 × 1 mm, rotation time 1s, pitch 1, slice thickness 1.25 mm, reconstruction increment 0.6 mm and reconstruction Field Of View (FOVmm : 150 × 150) with a matrix of 512. The tube voltage was set at 110 kV, the exposure time/tube current product was 30-50 mAs and the resulting CTDIvol for this protocol was 3.6 mGy/cm in average. The patient was placed in the prone position on the CT table-top with the arm raised above the head, in the so-called Superman position. Scanning extended from the distal one-third of the humerus to the elbow joint space. Most of the patients were immobilized by using a specific holder during the examination to reduce motion artifact. An initial planning image was obtained with a thin-section technique and the acquisition direction was cranio-caudal. For each CT examination, care was taken to optimize the selection of the kV and mAs according to the patient's body morphotype and to apply the dose reduction system (CARE Dose 4D : real time mAs modulation according to patient profile). Patients did not receive intravenous injection of contrast material.

Image analysis

Analysis was performed on the CT workstation. The multiplanar reformatted (MPR) images using sharp (B70), and the three-dimensional volume-rendering technique (VRT) images using smooth (B30) were systematically performed. MPR images were performed in coronal, sagittal and oblique planes to define the fracture extent in each plane, whereas 3D images were used to view the bone elbow structure as a volume.

To analyze the image quality, two segments were defined in the distal part of the humerus : medial and lateral columns which were connected by a thin segment of bone between the coronoid fossa anteriorly and the olecran fossa posteriorly. The CT interpretation focused on the study of the two cortices (anterior and posterior) of each column in order to analyze the cortical surface continuity, the type of its fracture (complete or greenstick) and the spatial direction of the displacement.

A paediatric radiologist interpreted all CT images. The results were discussed in an interdisciplinary colloquium with paediatric orthopaedist surgeons and compared to the radiographic findings before interventional procedure.

RESULTS

There were 63 patients in the study group with a male predominance (42 boys and 21 girls aged between 3 and 14 years). Majority of the fractures were caused by falls. Oblique radiographs were obtained in addition to AP and lateral views in 29 cases. Using Lagrange's system, 16 had SCH fracture type 2 with unidirectional displacement, and 47 had type 3 with multidirectional displacement.

CT-scans were performed in 32 of 63 patients. When analysing CT scans, we noted the following :

- In Lagrange type 2 (n = 6), the angulation was mainly posterior, and the posterior cortices of the medial and lateral columns were in continuity but were bent (greenstick fracture). However, the anterior cortex was completely broken. Displacement was only noted in the sagittal plane and there was no malrotation (Fig. 1 & 2).
- In Lagrange type 3 (n = 26), the displacement was multidirectional, including posterior tilt, translation, rotation and coronal angulation. However, the contact between bone fragments was maintained. CT-scan enabled us to distinguish two subtypes :
  - The first subtype (n = 12) had fracture of both the anterior and posterior cortices of the lateral column which was completely displaced, resulting in an unstable column. Yet, the medial column maintained its stability by preserving the continuity of its posterior cortex

Fig. 1. — Plain radiographs of a 4-year-old boy with a Gartland and Lagrange type 2 SCH. The AP view shows a slight displacement (20 degrees angulation) ; the lateral view shows a slight posterior angulation of the distal fracture fragment.

Fig. 3. — Plain radiographs (AP, oblique and lateral views) of 3-year-old boy with type 3 Lagrange displaced SCH fracture of the left elbow (Gartland type 2). Fracture is displaced with moderate posterior angulation and malrotation ; some contact remains between fragments.

Fig. 2. — Three-dimensional volume–rendered CT images of the elbow performed after plain radiographs (same patient as in Fig. 1). Volume-rendered 3D CT images (anterior, posterior and lateral views). CT images show fracture angulation with bent posterior cortex of the two columns.

Fig. 4. — Three-dimensional volume–rendered CT images of the elbow performed after plain radiographs (same patient in Fig. 3). Volume-rendered 3D CT images (posterior, anterior and lateral views). Complete split up of the 2 cortices (anterior and posterior) of the lateral column's making this column completely unstable. The medial column is partially stable with a moderate posterior angulation and a maintained continuity of its posterior bent cortex.

which was bent. This medial column represented the stable column and its posterior cortex thus represented a hinge and an axis which permitted the rotation displacement (Fig. 3 & 4).

- In the second type (n = 14), the medial column was completely displaced with a complete fracture of both its anterior and posterior cortices. This medial column represented the unstable column. The lateral column was the stable column with a complete fracture of its anterior cortex and a bending of its posterior cortex resulting in a malrotation in the coronal plane (Fig. 5 & 6).

Based on these observations, one of the authors (MS) started lateral percutaneous pin fixation under fluoroscopic control using a single pin, instead of two or three (*5,7,9,22*), after closed reduction for these greenstick SCH fractures. Intraoperative dynamic imaging was used to study the immediate stability of the fractures. This single and simple pin fixation was sufficient to stabilize the fracture in all the cases with good radiological and functional results at a mean follow-up of 16 months (Fig. 7a & 7b). We think that this new strategy of using a single pin may reduce the duration of surgery and the risk of pin-related complications.

DISCUSSION

Supracondylar humeral fractures are common injuries in children ; they are generally considered

Fig. 5. — Plain radiographs (oblique and lateral views) of 3-year-old boy with Lagrange type 3 right SCH displaced fracture (Gartland type 2). Fracture is displaced with angulation, but maintains an intact cortical hinge posteriorly.

Fig. 6. — Three-dimensional volume-rendered CT images, same patient as in Fig. 6 (Anterior, lateral, posterior and oblique views). Instability of the medial column and a partial bent posterior cortex of the lateral column which permit a malrotation in the coronal plane.

Fig. 7. — Postoperative plain radiograph of the patient in Figures 3 and 4. AP and lateral views taken six weeks postoperatively showing good reduction and consolidation (8a : Before and 8b : after removal of pins).

difficult to evaluate and to manage with plain radiography (*22,24*). They occur in children at different ages, mostly between 2 and 8 years of age (mean : 6 years) (*7,14,16*). Diagnosis is suspected based on clinical findings, and plain radiographs represent the most important tool for initial fracture diagnosis (*3,7,11,14*). The gold standard for initial evaluation is an AP view of the elbow in full extension and a lateral view in 90° flexion and a neutral position of the forearm. When fracture visualization remains unclear, oblique views may be helpful and may deliver more information.

In our study, standard radiographs were inaccurate owing to the difficulty to evaluate the degree of 3-D displacement, and to assess the exact location and extent of the fracture as well as its type.

Several classifications have been proposed, all based on two-dimensional radiographic analysis of these 3-D fractures and anatomy complexity (*4,5,12,14,20,22*). For the most part, these classifications do not reflect an underlying explanation or concept of bony injuries, which may be helpful in understanding the disparate patterns of 3-D bony displacement, which characterize the moderately displaced fractures.

The most used classifications are those of Lagrange and of Gartland, based on the analysis of the degree of displacement and angulation in both coronal and sagittal planes, but they do not consider the rotary displacement (*2,3,5,12,14,19,21,24*). As a consequence, the majority of authors overlook this important component of the displacement. To our knowledge, there have been no previous studies analyzing the component of rotation in displaced paediatric extension type supracondylar humeral fractures and its possible effect on treatment.

Wilkins modified the Gartland classification system and paid attention to unreported fracture types and greenstick fracture in type II. This author was first to describe this particular and common paediatric bone lesion in SCH fractures and he split up the Gartland type II into 2 subtypes : IIA with only sagittal posterior displacement and IIB with a rotary displacement (*2,10*). However Wilkins did not suggest any anatomical explanation for these 2 subtypes of displacement and his modified classification remains remains purely descriptive, without any therapeutic impact.

Attempting to reach the optimal understanding of the anatomical bone lesions and so the optimal classification of SCH fractures, we explored SCH fractures by CT-scan. In fact, CT has now become the technique of choice for imaging acute extremity trauma in many radiology departments. On the other hand, spiral CT has the advantage of rapid scanning time and 3D post-processing capabilities. To our knowledge, there have been no previous studies using CT-scan in exploring paediatric SCH fractures.

The 3-D CT construction has given us a much clearer view of the fracture patterns. The 32 CT-scans carried out allowed us to better understand these partially unstable fractures with special emphasis on the rotary component of the displacement, which is usually difficult to analyze on plain radiographs because of the complexity of the anatomy of the distal part of humerus. This procedure enabled us to distinguish three subgroups of partially displaced SCH fracture in the population studied. In the first subtype, only the anterior cortices of the 2 columns are completely fractured ; the 2 posterior cortices are continuous but have greenstick fractures. In the other two subtypes, there is a complete fracture of 3 cortices : 2 anterior and one posterior, and only one column (medial or lateral) preserves a continuous posterior cortex with a greenstick fracture.

The use of CT-scan has facilitated our understanding of the spatial displacement in extension type SCH fractures in children. This is, as far as we know, the first study evaluating the 3-D displacement and bone lesions of SCH fracture using CT scans. Several authors reported the value of CT-scan in classifying other fractures (*10,18*), but no study had evaluated the diagnostic accuracy of CT in the staging of SCH fractures in children.

Our CT-scan findings have provided an explanation for Gartland's modified classification (Wilkins's classification). We were also able to show the different components of the displacement. This allowed us to adapt an adequate therapeutic care and to propose a new therapeutic guideline relying on the stability of the columns.

Our study has however not resulted in the proposal of a new classification, as the reliability of our findings should be confirmed by further investigations on larger numbers of patients. The study is ongoing, and may soon result in a simple, accurate and reliable 3-dimensional classification which may find general acceptance. This will also have an impact on treatment.

Economic factors and radiation exposure may limit the use of CT scan. We think that economics must not be the only factor that influences the choice of the imaging technique. Concerning radiation exposure, the radiation dose associated with CT examination of the elbow was usually low in our study. Furthermore, this approach is not to be systematically used in all SCH fractures and it should be reserved to cases in which the analysis of plain radiographs is difficult.

CONCLUSION

Based on this study, we believe that CT scan could be the imaging technique of choice to evaluate some moderately displaced supracondylar humeral fractures in children when plain radiographs are insufficient to assess the rotary displacement. The experience gained from identifying the 3-D patterns of these fractures helped us to bring both classifications closer together (Lagrange's type 2 and 3 are represented by Gartland's type II). Besides, understanding the SCH fracture in three dimensions may potentially have a beneficial influence on the choice of the surgical procedures.

REFERENCES

1. **Akakpo-Numado GK, Mal-Lawane M, Belouadah M *et al.*** [Management of Lagrange and Rigault stage IV extension type supracondylar fracture of the humerus in children.] (in French). *Rev Chir Orthop* 2005 ; 91 : 664-674.
2. **Barton KL, Kaminsky CK, Green DW *et al.*** Reliability of a modified Gartland classification of supra condylar humerus fractures. *J Pediatr Orthop* 2001 ; 21 : 27-30.
3. **Brubacher JW, Dodds SD.** Pediatric Supracondylar fractures of the distal humerus. *Curr Rev Musculoskelet Med* 2008 ; 1 : 190-196.
4. **Bullen J.** Pediatric supracondylar humerus fractures. *Air Med J* 2004 ; 23 : 10-12.
5. **Cekanauskas E, Degliütë R, Kalesinskas RJ.** Treatment of supracondylar fractures in children according to Gartland classification. *Medicina* 2003 ; 39 : 379-383.
6. **Chen JC, Ng BK, Ying SY, Lam PK.** A 10-year study of the changes in the pattern and treatment of 6493 fractures. *J Pediatr Orthop* 1999 ; 19 : 344-350.
7. **Cordon JE, Patton CM, Luhmann SJ, Bassett GS, Schoenecker PL.** Fracture stability after pinning of displaced supracondylar distal humerus fracture in children. *J Pediatr Orthop* 2001 ; 21 : 313-318.
8. **Crombie A, Duncan R.** Closed reduction and percutaneous fixation of displaced paediatric supracondylar fractures of the elbow. *Curr Orthop* 2004 ; 18 : 147-153.
9. **Crowther M.** Elbow pain in paediatrics. *Curr Rev Musculoskelet Med* 2009 ; 2 : 83-87.
10. **Edelson G, Kelly I, Vigder F, Reis ND.** A three-dimensional classification for fractures of the proximal humerus. *J Bone Joint Surg* 2004 ; 86-B : 413-425.
11. **Hindman BW, Schreiber RR, Wiss DA, Ghilarducci MJ, Avolio RE.** Supracondylar fractures of the humerus : prediction of the cubitus varus deformity with CT. *Radiology* 1988 ; 168 : 513-515.
12. **Jeffrey WU, Perron AD, Miller MD, Powell SM, Brady W.** Orthopedic pitfalls in the ED : pediatric supracondylar humerus fractures. *Am J Emerg Med* 2002 ; 20 : 544-550.
13. **Journeau P, Annocaro F.** Supracondylar humeral fracture. In : Lascombes P (ed) *Flexible Intramedullary Nailing In Children* (Part II), 1st ed. Springer-Verlag, Berlin Heidelberg, 2010, pp 115-136.
14. **Kuo C, Widmann R.** Reduction and percutaneous pin fixation of displaced supracondylar elbow fractures in children (technique). *J Shoulder Elbow Surg* 2004 ; 5 : 90-102.
15. **Lagrange J, Rigault P.** [Supracondylar fractures.] (in French). *Rev Chir Orthop* 1962 ; 48 : 337-414.
16. **Landin LA.** Fracture patterns in children. Analysis of 8682 fractures with special reference to incidence, etiology and secular changes in a Swedish urban population 1950-1979. *Acta Orthop Scand* 1983 ; 202 (Suppl) : 1-109.
17. **Landin LA, Danielsson LG.** Elbow fractures in children, an epidemiological analysis of 589 cases. *Acta Orthop Scand* 1986 ; 57 : 309-312.
18. **Macarini L, Murione M, Marini S *et al.*** Tibial fracture : evaluation with multi detector-CT. *Radiol Med* 2004 ; 108 : 503-514.
19. **Minkowitz B, Busch MT.** Supracondylar humerus fractures. *Orthop Clin North Am* 1994 ; 25 : 581-594.
20. **Omid R, Choi PD, Skaggs L.** Supracondylar humeral fractures in children. *J Bone Joint Surg* 2008 ; 90-A : 1121-1132.
21. **Pirone AM, Graham HK, Krajbich JI.** Management of displaced extension-type Supracondylar fractures of the humeraus in children. *J Bone Joint Surg* 1988 ; 70-A : 641-650.
22. **Shrader MW.** Pediatric supracondylar fractures and pediatric physeal elbow fractures. *Orthop Clin North Am* 2008 ; 39 : 163-171.
23. **Tamai J, Lou J, Nagda S, Ganley T, Flynn JM.** Pediatric elbow fractures : pearls and pitfalls. *University Pennsylvania Orthop J* 2002 ; 15 : 43-51.
24. **Wilkins KE.** Fractures and dislocations of the elbow region. In : Rockwood CA Jr, Wilkins KE, King RE (eds). *Fractures in Children* (Vol 3), 4th ed, Lippincott-Raven, Philadelphia, 1996, pp 363-575.