RBO REVISTA BRASILEIRA DE ORTOPEDIA
www.rbo.org.br

Original Article

Do computed tomography and its 3D reconstruction increase the reproducibility of classifications of fractures of the proximal extremity of the humerus?☆,☆☆

Thaís Matsushigue, Valmir Pagliaro Franco, Rafael Pierami, Marcel Jun Sugawara Tamaoki, Nicola Archetti Netto, Marcelo Hide Matsumoto*

Universidade Federal de São Paulo, São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 4 September 2012
Accepted 1 August 2013
Available online 27 March 2014

Keywords:
Fractures of the humerus/radiography
Fractures of the humerus/classification
Tomography

ABSTRACT

Objective: to determine whether 3D reconstruction images from computed tomography (CT) increase the inter and intraobserver agreement of the Neer and Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification systems.
Methods: radiographic images and tomographic images with 3D reconstruction were obtained in three shoulder positions and were analyzed on two occasions by four independent observers.
Results: the radiographic evaluation demonstrated that using CT improved the inter and intraobserver agreement of the Neer classification. This was not seen with the AO classification, in which CT was only shown to increase the interobserver agreement.
Conclusion: use of 3D CT allows better evaluation of fractures with regard to their component parts and their displacements, but nevertheless the intraobserver agreement presented is less than ideal.

A tomografia computadorizada e sua reconstrução 3D aumentam a reprodutibilidade das classificações das fraturas da extremidade proximal do úmero?

Palavras-chave:
Fraturas do úmero/radiografia
Fraturas do úmero/classificação
Tomografia

RESUMO

Objetivo: determinar se as imagens da reconstrução 3D da tomografia computadorizada (TC) aumentam a concordância inter e intraobservador dos sistemas de classificação de Neer e Arbeitsgemeinschaft für Osteosynthesefragen (AO).

☆ Please cite this article as: Matsushigue T, Franco VP, Pierami R, Tamaoki MJS, Netto NA, Matsumoto MH. A tomografia computadorizada e sua reconstrução 3D aumentam a reprodutibilidade das classificações das fraturas da extremidade proximal do úmero?. Rev Bras Ortop. 2014;49:174–177.

☆☆ Work performed in the Department of Orthopedics, Escola Paulista de Medicina, Universidade Federal de São Paulo.

* *Corresponding author.*
E-mail: rpierami@gmail.com (R. Pierami).

2255-4971/$ – see front matter
http://dx.doi.org/10.1016/j.rboe.2014.03.016

Métodos: foram obtidas imagens radiográficas em três posições do ombro e imagens tomográficas com reconstrução 3D, que foram analisadas em dois tempos por quatro observadores independentes.

Resultados: a avaliação radiográfica demonstrou que o uso da TC melhora a concordância intra e interobservadores para a classificação de Neer. O mesmo não foi observado na classificação AO, na qual a TC demonstrou aumento somente da concordância interobservadores.

Conclusão: o uso de TC 3D permite uma melhor avaliação da fratura quanto às partes que a compõem e aos seus desvios, mas mesmo assim apresenta uma concordância intraobservadores menor do que a ideal.

Introduction

Fractures of the proximal extremity of the humerus have an incidence of approximately 63–105 per 100,000 per year[1–4] and account for 5% of all injuries to the appendicular skeleton.[4,5] Their incidence is low among individuals under the age of 40 years and increases exponentially after this age. There is greater prevalence of these fractures among women, and female cases account for around 70–80%.[1–5] The characteristics of the fracture (line, location, joint involvement, comminution and degree of soft-tissue involvement) are directly related to the force of the trauma, position of the limb at the time of the trauma and bone quality.[6,7]

Several classification systems have been developed in an attempt to guide treatments and compare results. For a classification system to be considered good, it needs to be validated, reliable and reproducible, as well as guiding the treatment, predicting possible complications and providing a prognosis. Furthermore, it should function as a mechanism for comparing the results obtained from the different types of treatment.

The classification method of the Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation (AO/ASIF), which was created in 1986 and revised in 1990, uses an alphanumeric system for dividing fractures of the proximal extremity of the humerus into 27 subgroups. Three basic types of injury are taken into consideration in this classification method: extra-articular single-focus fractures, extra-articular bifocal fractures and joint fractures. The three groups are organized in increasing order of complexity and treatment difficulty and according to the prognosis. This is one of the most complete classification systems, but its intra- and interobserver reproducibility have been shown to be problematic with regard to the divisions between groups and subgroups.[8]

Neer used the parts defined by Codman to propose the classification system that today is most frequently used.[9,10] The four parts of the proximal extremity of the humerus defined in this classification method are the greater tuberosity, lesser tuberosity, diaphysis of the humerus and humeral head. For these parts to be considered to be fractured, the fragment should have a displacement greater than 1 cm or 45°, except for the greater tuberosity, which is considered to be a fractured part if there is a displacement greater than 0.5 cm or an angle of 45°. Thus, the fractures can be classified as affecting one, two, three or four parts. One criticism of Neer's classification is that it does not consider the possibility of glenohumeral dislocation associated with the fracture, whereas this is encompassed in the AO classification.

Recently, come studies have questioned the reproducibility of classifications of fractures of the proximal extremity of the humerus.[11–16] The main criticism of these classification systems relates to the difficulty of assessing the degree of displacement and angulation through using simple radiographs alone. In this regard, computed tomography (CT) provides greater detailing of the injury and has been widely used for evaluating these fractures, especially in situations of greater complexity. However, this examination is not harmless: the patient receives a high dose of radiation. Moreover, its indications are still not well established and its benefit is not clearly proven.[12,13,16]

Given that treatment of these fractures depends on the radiographic evaluation and that the classification systems most used (AO and Neer) present low reproducibility,[11–13] we developed the present study with the aim of evaluating the reproducibility of the two classification systems most used in our setting, by means of radiography and CT with 3D reconstruction.

Materials and methods

This study was submitted for appraisal by the Research Ethics Committee of the Federal University of São Paulo (UNIFESP) under the number 0212/11, on February 24, 2011, and was approved.

A retrospective analysis was conducted on all the patients with a diagnosis of fracturing of the proximal extremity of the humerus attended in the Shoulder and Elbow Surgery Sector of Hospital São Paulo, UNIFESP, between August 2009 and April 2012.

Seventy-two consecutive patients were selected, of whom 37 could be included in the study. The images selected were analyzed according to the views obtained (anteroposterior, lateral scapular and axillary), the total number of views, the quality of the radiographs and the use of CT with 3D reconstruction at the time of the trauma. Radiographs were excluded if their quality was poor, if the views needed for the study were not available or if no CT images with 3D reconstruction were available. Furthermore, all patients who had undergone previous surgical procedures on the limb under examination, those who had previously had fractures in the

region studied and those presenting fractures that were considered to be pathological were also excluded.

The images were analyzed by four independent observers: one third-year resident in orthopedics and traumatology (C); one trainee orthopedist in the shoulder and elbow sector (B); and two orthopedics and traumatology specialists in the field of shoulder and elbow surgery (A and D). These observers independently classified the fractures in accordance with the AO/ASIF and Neer classification methods, by means of analysis on images that had previously been digitized. These analyses were done twice, at two separate times with a one-week interval between them. At the two evaluations, the images were randomized into different sequences so as to avoid bias.

The data were gathered and subjected to statistical analysis. The kappa coefficient (κ) was obtained in order to determine the inter- and intraobserver concordance of the classifications. The kappa values varied from −1 to +1; values between −1 and 0 indicated that the concordance was less than expected and attributable purely to chance; values of 0 indicated that the concordance with similar to chance; and values of +1 indicated total concordance. Generally, values of 0.5 are considered to be unsatisfactory, values between 0.5 and 0.75 are satisfactory and appropriate and values greater than 0.75 are excellent.[17]

Results

The method with greatest interobserver concordance was the Neer classification using CT ($\kappa = 0.57$). CT provided greater interobserver concordance in both classifications (Table 1).

In relation to intraobserver concordance, no increase was observed through using CT applied to the AO classification ($\kappa = 0.39$ for radiography and $\kappa = 0.33$ for CT). However, for the Neer classification, there was an increase in this concordance ($\kappa = 0.45$ for radiography and $\kappa = 0.56$ for CT) (Table 2).

Table 1 – Interobserver concordance using radiography and CT examinations with the Neer and AO classification systems.

Examination	Classification	Kappa
Radiography	Neer	0.37
	AO	0.25
Tomography	Neer	0.57
	AO	0.36

Table 2 – Mean intraobserver concordance for the Neer and AO classification systems when CT and X-ray examinations were used.

Examination	Classification	Kappa
Radiography	Neer	0.45
	AO	0.39
Tomography	Neer	0.56
	AO	0.33

Discussion

Over recent decades, with the introduction of new technologies for diagnosing fractures of the proximal extremity of the humerus, it has been asked whether using CT with three-dimensional reconstruction (3D CT) might provide benefits with regard to identifying the fracture pattern and guiding the type of treatment to use.[11–16] However, CT is not a harmless method, because it exposes the patient to a high dose of radiation. Moreover, the cost of this method is still much higher than that of simple radiography. For these reasons, new studies should be conducted to define the usefulness and possible indications for using CT.

In our study, the interobserver concordance using the Neer classification by means of radiographs was unsatisfactory ($\kappa = 0.37$). This finding is in agreement with other published studies that had this aim.[12,13,18] When the evaluation was done using CT, the interobserver concordance became satisfactory ($\kappa = 0.57$), as also seen in other studies already published,[12,13] which justifies the use of CT. In relation to the AO classification, the values found using radiography and CT were considered to be unsatisfactory, even though there was an increase in the kappa value ($\kappa = 0.25$ for radiography and $\kappa = 0.36$ for CT). These unsatisfactory values can perhaps be explained by the complexity of the classification system. The same is observed when the system is used to classify fractures in other segments, such as the distal extremity of the radius, the ankle or the femoral neck.[19–22]

In relation to interobserver concordance, CT was shown to be useful when the Neer classification was used, and produced a satisfactory value ($\kappa = 0.56$). This has also been shown by other studies.[11,12,18] For the AO classification, CT was not shown to be useful and led to a decrease in the kappa value (from 0.39 to 0.33), which perhaps can be explained by the complexity of the classification system, as discussed earlier.

Thus, our study demonstrated that the Neer classification was more reproducible when CT with 3D reconstruction was used, which therefore justifies its use in classifying fractures of the proximal extremity of the humerus, which is what it is most used for in our setting. Nonetheless, in absolute values, the reproducibility still remains low. This was not observed when the AO classification was used.

One limitation of this study was the low number of cases evaluated, which may have led to bias. Furthermore, because this study was conducted at a reference service for trauma, it is likely that there were greater numbers of complex cases among the sample, which would lead to lower intra- and interobserver concordance, considering that in cases of fractures of the proximal extremity of the humerus of greater complexity, it becomes more difficult to measure the angular deviation, displacement and impaction. These characteristics of the fracture, which form part of the criteria for the classification, have been indicated to be the factors that cause low reproducibility of the classifications. It is important to emphasize that the present study only aimed to investigate the reproducibility of the classification systems using conventional radiographs and CT with 3D reconstruction. This was not an accuracy study, nor did it assess the merit of these examinations regarding surgical indications.

Conclusion

CT with 3D reconstruction improved the intra- and interobserver concordance for the Neer classification method. This was not observed for the AO classification system, in which only interobserver concordance was seen to improve with the use of CT with 3D reconstruction.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand. 2001;72(4):365–71.
2. Horak J, Nilsson BE. Epidemiology of fracture of the upper end of the humerus. Clin Orthop Relat Res. 1975;(112):250–3.
3. Kristiansen B, Barfod G, Bredesen J, Erin-Madsen J, Grum B, Horsnaes MW, et al. Epidemiology of proximal humeral fractures. Acta Orthop Scand. 1987;58(1):75–7.
4. Lind T, Krøner K, Jensen J. The epidemiology of fractures of the proximal humerus. Arch Orthop Trauma Surg. 1989;108(5):285–7.
5. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury. 2006;37(8):691–7.
6. Palvanen M, Kannus P, Parkkari J, Pitkäjärvi T, Pasanen M, Vuori I, et al. The injury mechanisms of osteoporotic upper extremity fractures among older adults: a controlled study of 287 consecutive patients and their 108 controls. Osteoporos Int. 2000;11(10):822–31.
7. Mills HJ, Horne G. Fractures of the proximal humerus in adults. J Trauma. 1985;25(8):801–5.
8. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium – 2007 Orthopaedic Trauma Association classification, database, and outcomes committee. J Orthop Trauma. 2007;21 Suppl. 10:S1–133.
9. Neer CS. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am. 1970;52(6):1077–89, 2nd.
10. Neer CS. Four-segment classification of proximal humeral fractures: purpose and reliable use. J Shoulder Elbow Surg. 2002;11(4):389–400, 2nd.
11. Bernstein J, Adler LM, Blank JE, Dalsey RM, Williams GR, Iannotti JP. Evaluation of the Neer system of classification of proximal humeral fractureswith computerized tomographic scans and plain radiographs. J Bone Joint Surg Am. 1996;78(9):1371–5.
12. Brunner A, Honigmann P, Treumann T, Babst R. The impact of stereo-visualisation of three-dimensional CT datasets on the inter- and intraobserver reliability of the AO/OTA and Neer classifications in the assessment of fractures of the proximal humerus. J Bone Joint Surg Br. 2009;91(6): 766–71.
13. Foroohar A, Tosti R, Richmond JM, Gaughan JP, Ilyas AM. Classification and treatment of proximal humerus fractures: inter-observer reliability and agreement across imaging modalities and experience. J Orthop Surg Res. 2011 29;6: 38.
14. Siebenrock KA, Gerber C. The reproducibility of classification of fractures of the proximal end of the humerus. J Bone Joint Surg Am. 1993;75(12):1751–5.
15. Mahadeva D, Dias RG, Deshpande SV, Datta A, Dhillon SS, Simons AW. The reliability and reproducibility of the Neer classification system – Digital radiography (PACS) improves agreement. Injury. 2011;42(4):339–42.
16. Sjödén GO, Movin T, Aspelin P, Güntner P, Shalabi A. 3D-radiographic analysis does not improve the Neer and AO classifications of proximal humeral fractures. Acta Orthop Scand. 1999;70(4):325–8.
17. Fleiss JL, Slakter MJ, Fischman SL, Park MH, Chilton NW. Inter-examiner reliability in caries trials. J Dent Res. 1979;58(2):604–9.
18. Majed A, Macleod I, Bull AM, Zyto K, Resch H, Hertel R, et al. Proximal humeral fracture classification systems revisited. J Shoulder Elbow Surg. 2011;20(7):1125–32.
19. Matsunaga FT, Tamaoki MJ, Cordeiro EF, Uehara A, Ikawa MH, Matsumoto MH, et al. Are classifications of proximal radius fractures reproducible? BMC Musculoskelet Disord. 2009;10:120.
20. Belloti JC, Tamaoki MJ, Franciozi CE, Santos JB, Balbachevsky D, Chap Chap E, et al. Are distal radius fracture classifications reproducible? Intra interobserver agreement. Sao Paulo Med J. 2008;126(3):180–5.
21. Tenório R, Mattos CA, Araujo LH, Belangero WD. Análise da reprodutibilidade das classificações de Lauge-Hansen e Danis-Weber para fraturas de tornozelo. Rev Bras Ortop. 2001;36(1):434–7.
22. Gusmão PD, Mothes FC, Rubin LA, Gonçalves RZ, Telöken MA, Schwartsmann CR. Avaliação da reprodutibilidade da classificação de Garden para fraturas do colo femoral. Rev Bras Ortop. 2002;37(8):381–6.