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Original Article

Correlation study on anatomical parameters of bicipital groove and retroversion angle of humeral head

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Abstract: Introduction: This research was to study the anatomical features of the retroversion angle of humeral heads (RA) and the bicipital groove among Asian population using CT and to make correlation between RA and two parameters of bicipital groove. The two parameters of bicipital groove were the distance between bicipital groove and the central axis of humeral head (Distance D), and bicipital groove orientation. Methods: Twenty dry adult humeral specimens from an anatomy department of a medical college underwent spiral CT scan. RA and the two anthropometric parameters of the bicipital groove on transverse plane including the initial part of the bicipital groove (IP slice), the plane where the humeral head had the largest diameter (LD slice), and the surgical neck (SN slice) were measured. Statistical analysis was performed to evaluate the features of the parameters and the correlation coefficient between these parameters. Results: The average RA was 32.10 ± 14.10 (range: 0.43-54.69) without statistical difference between the left and the right side. Both the correlation coefficient between Distance D and RA and the correlation coefficient between bicipital groove orientation and RA were significantly negative on IP slices and insignificantly negative on LD slices. On SN slices, the correlation coefficient between Distance D and RA was negative without statistical difference (P=0.06); the correlation coefficient between bicipital groove orientation and RA was significantly negative (P=0.027). Conclusions: There was a negative correlation between Distance D and RA, and between bicipital groove orientation and RA. These anatomical data are probably helpful for orthopedic surgery.

Keywords: Bicipital groove, bicipital groove orientation, retroversion angle of the humeral head, correlation coefficient

Introduction

Humeral head retroversion angle (RA) affects the mobility and stability of the shoulder. Correct RA influences the position of the instant center of rotation, the stability of the joint [1] and the amount of external rotation [2, 3]. Therefore, reproduction of RA is clinically critical when performing humeral prosthesis implantation, total shoulder arthroplasty and other shoulder surgery [4]. For example, there are many literatures on total shoulder arthroplasty in which the authors recommended a retroversion angle varying from 30° to 40° for the humeral head in shoulder arthroplasty surgeries [5-7]. However, it has been confirmed in anatomical studies that there is considerable variation in RA in general population(Kummer et al. 1998). Thus, there is considerable controversy in adopting identical retroversion angle in total shoulder arthroplasty [8-10]. Taking individual difference into consideration is considered as beneficial to the surgery and prognosis.

However, establishing RA is still controversial. This is attributed to several factors, including the definition of RA, different measuring methods, ranges of normal values, and the accuracy of anatomic landmarks to guide determination of RA [11]. Doyle et al. performed a MRI study on 41 volunteers and 9 corpses and revealed a linear correlation between the distance from bicipital groove to central axis of humeral head and RA [12]. Hempfing et al. studied 50 macerated humeri on the correlation between the bicipital groove to the equatorial plane of the humeral head on four levels (proximal, distal and two intermediate) using bicipital groove as a landmark for adjusting RA [13].

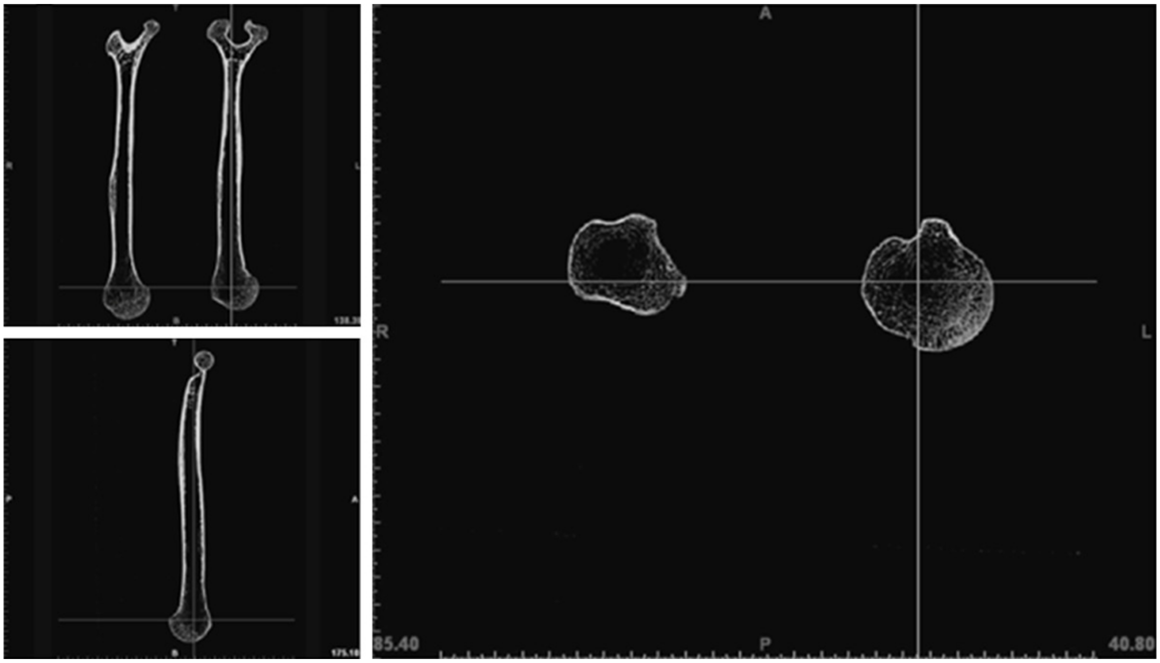

Figure 1. Positioning of central axis of the proximal humerus and the central axis point.

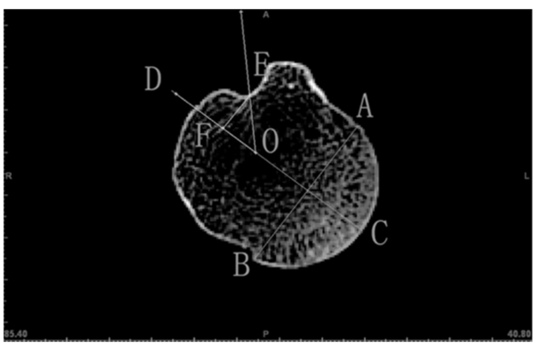

Figure 2. IP slice, with the largest diameter of humeral head. Line AB was the diameter of humeral head. Line CD was the central axis line of humeral head. ∠EOD was bicipital groove orientation. The distance between point E and F was the distance from bicipital groove to axis of humeral head.

Bicipital groove was used as a bony landmark to determine RA in many previous studies [3, 14]. Krummer et al. found that determining RA simply on one bicipital groove could help reduce the error in retroversion angle as much as 10° compared with applying standard retroversion angle to all patients [15].

Most of the previous studies were conducted on Caucasian populations. It may not be appropriate to similarly apply their findings to Asian population due to the anthropometric differences between different population groups. In this study, we evaluated the correlation between RA and two anthropometric parameters of the bicipital groove including the distance between bicipital groove and the central axis of humeral head (Distance D), and orientation of the bicipital groove on three levels. We hypothesized that bicipital groove could be used as bony landmark to guide the reproduction of RA.

Materials and methods

Twenty dried adult humeral specimens (10 left and 10 right) provided by the Anatomy Department of Weifang Medical College were included in this study. Those specimens with fractures, missing parts or pathological changes were excluded. The study was approved by Ethics Association of Weifang City.

Ultrahigh speed 64-rows multi-slice spiral CT scanner (Siemens, Germany) was used to obtain images of the specimens. The scanning parameters were set at 120 KV for the tube voltage, 120-150 mAs for the tube current, 1.5 mm for the collimator width, and 5 mm for the thickness of slices. Continuous scanning was performed with 0.75 mm overlapping and 2 mm reconstruction thickness. All humeri were

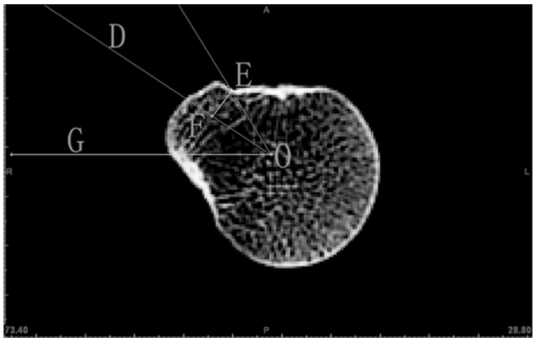

Figure 3. LD slice that taken from the initial portion of the bicipital groove.

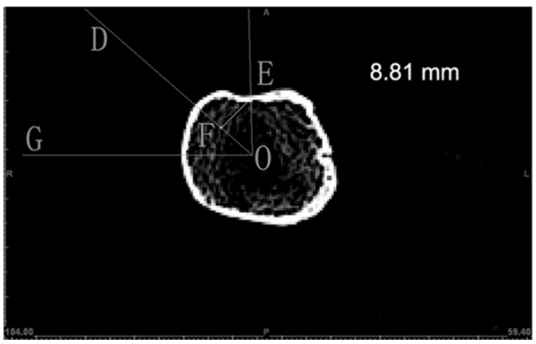

Figure 4. SN slice that taken from the surgical neck of the humerus.

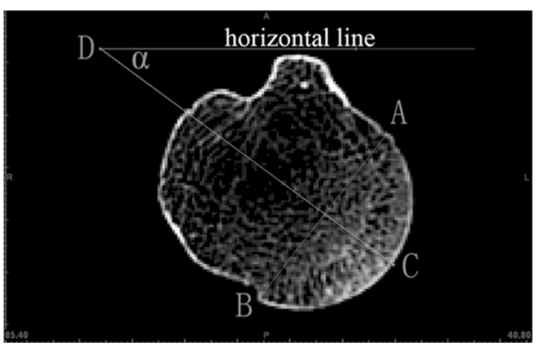

Figure 5. Line CD was the central axis of humeral head, and α was the angel between line CD and horizontal line.

placed in supine position, with longitudinal axis of the humerus parallel to the long axis of examination bed.

Measurement of distance d and the bicipital groove orientation

Images were processed by Mimics Version 8.11. The images with the largest diameter of the proximal humeral medullary cavity on the

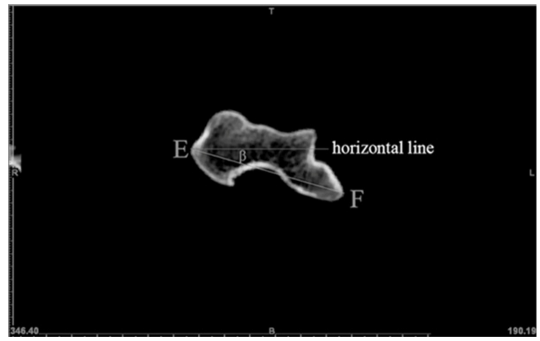

Figure 6. Line EF was between internal and external humeral epicondyles, β was the angle between EF and horizontal line, α-β was retroversion angle of humeral head.

coronal plane and the sagittal plane were used. A line was drawn between the midpoint of the proximal humerus and the midpoint of the medullary cavity to produce the axis line of the proximal humeral medullary cavity (**Figure 1**). The axis point was marked as point O on the horizontal plane.

Three slices of transverse plane were used for the measurement. The first slice was taken from the initial part of the bicipital groove (IP slice) (**Figure 2**). The second slice was taken from the plane where the humeral head had the largest diameter (LD slice) (**Figure 3**). The third slice was taken from the surgical neck (SN slice) (**Figure 4**). On these slices, articular edges of the humeral heads were easily identified. Points with the widest gap on the humeral head were connected to form the line AB which was the largest diameter of the humeral head. The perpendicular bisector of AB was drawn to form line CD. CD was used as the central axis of the humeral head (actually line CD may be located somewhat behind point O due to the eccentricity of the humeral head).

The angles between line CD and horizontal line were measured and recorded. Line EO between the lowest point of the bicipital groove E and O was drawn. The angle between line CD and line EO was the angle between bicipital groove and the central axis line of humeral head, which was defined as bicipital groove orientation. A perpendicular line EF through the lowest point E of bicipital groove against the central axis line of humeral head (line CD) was drawn. The perpendicular distance between bicipital groove and the central axis of humeral head was

Table 1. Measurements on retroversion angle of humeral head and the comparison between left and right side

Test Parameters	Group	Mean ± SD	Range	F	P
RA	Left	31.47 ± 15.22	0.43-54.69	0.002	0.966
	Right	31.76 ± 14.80	8.31-51.00		

Distance D. Finally, Distance D and bicipital groove orientation were measured.

Measurement of RA

RA was measured as follows: Plane A (Coronal plane of humeral head) was formed by the long axis of humerus and central axis of humeral head. Plane B (Coronal plane of humeral condyle or trochlea) was formed by the long axis of humerus and the axis lines of distal medial and lateral humeral epicondyles or the axis of trochlea. The angle between these two planes was taken as RA. LD slices were used for the measurement of RA. The angle between the central axis of the humeral head and the horizontal line was denoted as α and measured (**Figure 5**). Another slice from the distal end of humerus with the most prominent medial and lateral humeral epicondyles was used. A line was drawn between the tops of the medial and lateral humeral epicondyles. The angle between this line EF and the horizontal line was marked as β and measured. The angle α-β was RA (**Figure 6**).

Statistical analysis

The data were expressed as mean ± SD and the statistical analysis was performed using SPSS 17.0. The correlation between Distance D, bicipital groove orientation and RA was analyzed by ANOVA and Pearson correlation coefficient. $P < 0.05$ was taken as statistical difference.

Results

The average RA of the 20 humeral heads was 32.10 ± 14.10° (range: 0.43-54.69°) in average. The right RA was 31.76 ± 14.80° and the left RA was 31.47 ± 15.22°. The one-way ANOVA test for the left RA and the right RA showed no statistical difference with F=0.002 and P=0.966 (**Table 1**).

On IP slice (**Table 2**), Distance D was 7.71 ± 2.44 mm. The correlation coefficient between Distance D and RA was 0.569. The result of the significance test was P=0.009, indicating there was a significant negative correlation between Distance D and RA. Bicipital groove orientation was 35.09 ± 10.78°. The correlation coefficient between bicipital groove orientation and the retroversion angle was -0.488 (P=0.029). It suggested that there was a significant negative correlatioin between bicipital groove orientation and RA.

On LD slices (**Table 2**), Distance D was 9.06 ± 2.51 mm. The correlation coefficient between Distance D and RA was -0.351 without statistical difference (P=0.130). Position angle on LD slices was 36.48 ± 9.44°. The coefficient between the position angle and RA was -0.317 (P=0.173), suggesting the correlation between bicipital groove orientation and RA on LD slices had no statistical significance.

On SN slices, Distance D was 7.30 ± 1.63 mm (**Table 2**). The correlation coefficient between Distance D and RA was -0.428 without statistical difference (P=0.06). The position angle of bicipital groove on SN slices was 39.78 ± 8.55° and its correlation coefficient with RA on SN slices was -0.494 (P=0.027). It suggested that there was a significant negative correlation between bicipital groove orientation and RA on SN slices.

Discussion

RA is not well described with the literature controversial regarding accuracy of measurement methods and ranges of normal values [2]. Treatment of a variety of shoulder abnormalities requires a thorough knowledge of normal values of RA and an accurate objective method for determination and reproduction of RA of the patient [4, 16]. In the present study, the results showed that the left RA and the right RA had no statistical difference. On IP slice, both the correlation coefficient between Distance D and RA and the correlation coefficient between bicipital groove orientation and RA were significantly negative. On LD slices, both the correlation coefficient between Distance D and RA and the correlation coefficient between bicipital groove orientation and RA were negative without sta-

Table 2. Distance D, bicipital groove orientation and the comparison between left and right humeri

	Parameters	Left/Right	Means	Range	F	P
IP slices	Distance D	Left (n=10)	7.41 ± 2.63	2.81-11.01		
		Right (n=10)	8.02 ± 2.33	4.41-11.89	0.30	0.59
		Total (n=20)	7.71 ± 2.44	2.81-11.89		
	Bicipital groove orientation	Left (n=10)	36.34 ± 10.92	16.78-52.78		
		Right (n=10)	33.85 ± 11.08	14.23-56.32	0.255	0.619
		Total (n=20)	35.09 ± 10.78	14.23-56.32		
LD slices	Distance D	Left (n=10)	8.79 ± 2.61	4.98-13.06		
		Right (n=10)	9.33 ± 2.52	6.42-13.60	0.221	0.644
		Total (n=20)	9.06 ± 2.51	4.98-13.60		
	Bicipital groove orientation	Left (n=10)	38.01 ± 9.47	24.36-49.03		
		Right (n=10)	34.96 ± 9.65	24.20-55.84	0.510	0.484
		Total (n=20)	36.48 ± 9.44	24.20-55.84		
SN slices	Distance D	Left (n=10)	7.27 ± 1.66	4.19-9.66		
		Right (n=10)	7.33 ± 1.69	5.51-10.43	0.007	0.935
		Total (n=20)	7.30 ± 1.63	4.19-10.43		
	Bicipital groove orientation	Left (n=10)	40.23 ± 9.13	22.85-51.84		
		Right (n=10)	39.33 ± 8.39	29.26-60.02	0.053	0.820
		Total (n=20)	39.78 ± 8.55	22.85-60.02		

tistical significance. On SN slices, the correlation coefficient between Distance D and RA was negative without statistical difference (P=0.06); the correlation coefficient between bicipital groove orientation and RA was significantly negative (P=0.027).

Our study found an average Distance D of 7.71 ± 2.44, 9.06 ± 2.51 mm and 7.30 ± 1.63 on IP slices, LD slices and SN slices respectively. Doyle et al. reported that the distance from bicipital groove to the central axis was 11.8 mm ± 2.35 mm [12]. Hempfing et al. reported that the distance from the bicipital groove to the equatorial plane (axial plane) of the humeral head on four sequential levels were 8.0 ± 1.4 mm, 10.2 ± 1.4 mm, 10.1 ± 1.3mm and 8.5 ± 1.1 mm [13]. With the limitation of small sample size of the present study, the results showed that Distance D for Asian population seemed much shorter and varied compared with Hempfing et al.'s study [13]. The result also showed that RA in Asian population was 32.10 ± 14.10° (range 0.43-54.69°) with a more apparent inter-individual variability compared with average RA of 12.3 ± 7.9° (range 2-45°) in Guenoun et al.'s study [11]. Maybe, using the data obtained from the previous studies to guide the surgeries on Asian population would result in small errors, such as, making the retroversion angle of the prosthesis larger. But it has to be further studied.

The present study showed that there was a significant negative correlation between bicipital groove orientation and RA at initial portion of the bicipital groove. The correlation coefficient between bicipital groove orientation and RA on IP slice, LD slice, and SN slice were different. We suggested that the initial portion of bicipital groove seemed to be the most reliable landmark, which was followed by surgical neck of bicipital groove. These findings were in accordance with the previous studies that the surgical neck of humerus could be used as a reference mark in total shoulder arthroplasty [2]. It should be noted that our findings were slightly different from the results of Hempfing et al. who found a significant correlation between RA and the distance between the bicipital groove and the equatorial plane at the distal portion of the bicipital groove [13]. This difference could be attributed to the different measure protocols and different population groups. Additionally, the limited sample size in both researches would influence the results.

The present study showed that there was no statistical difference between RA of the left side and RA of the right side. Some studies showed a considerable difference between the left and right [17], whereas some reported none [6, 18]. Many authors found the bicipital groove was a useful anatomic landmark for guiding anatomic recreation of RA [3, 14]. However, researchers must be careful on the measurement because bicipital groove is S-shaped in some degree with the groove being more retroverted distally. Moreover, it has to be further studied because the insignificant difference between RA of the left and RA of right side could also be attributed to the possibility that some of specimens were obtained from left handed people. Previous studies have found significant differences between RA of the dominant and non-dominant humeri [19, 20]. We were not able to group the specimens by hand dominance because of the unavailable data.

This research has several limitations. Firstly, the findings of this research have to be confirmed by further study due to the small specimen sample size. Secondly, we took assumption that central axis of the humeral head approximately went through the axis of proximal humeral medullary cavity and the eccentricity of the humeral head was ignored. Though the assumption is accepted in most prosthesis designs and operating specifications. This may cause some deviations from the normal anatomy measurements. Further studies with better design and larger sample sizes should be undertaken.

In conclusion, there was a negative correlation between Distance D and RA, and between bicipital groove orientation and RA. These anatomical data are probably helpful for orthopedic surgery. Further study is needed.

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Disclosure of conflict of interest

None.

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