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Version reckoning of variant glenoid levels: a radiological study on dry human scapulae

Amr Elshahhat[1]*, Aya Mohammed Abdel Aziz[2], Yehia Basyoni[1], Khaled Ayman Nour[1]

[1]Department of Orthopedic Surgery, [2]Department of Diagnostic and Interventional Radiology, Mansoura University, Egypt

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***Correspondence:**
Dr. Amr Elshahhat,
E-mail: amrelshahat@mans.edu.eg

ABSTRACT

Background: Preoperative glenoid version measurement can guide base plate implantation and directing screws positioning. Glenoid vault depth affects guide-wire insertion with accurate inclinations towards maximum bone stock. No consensus exists regards the precise glenoid level for version assessment, whether at midaxial or coracoid tip level, and if those values are identical or not. Additionally, there is not much data in literature concerning the deepest point of glenoid vault and its proximity to anterior and inferior glenoid surfaces. Thus, we aimed in this study to report glenoid version values at all levels utilizing two different methodologies (Freidman method, vault version method). Additionally, detecting deepest vault point and how much distant from anterior and inferior glenoid aspects.
Methods: Sixty dry, unpaired scapulae were scanned with 1.25mm-thick slices. Version was measured at all levels and compared. Axial and coronal slices with greatest vault depth was determined and distance from anterior and inferior glenoid rims were determined.
Results: Version method showed significant difference in version at coracoid tip and midaxial levels ($p<0.001$). Mean versions were 18.2±10.6º and 8.9±6.8º respectively. Also, significant difference was noted between version of upper, middle, and lower thirds, except between middle and lower thirds. A significant difference was evident between both methodologies on comparing version at coracoid tip level ($p<0.001$).
Conclusions: Glenoid version at coracoid tip and midaxial levels are not the same. Correlation of preoperative version values with intraoperative situations might be studied in future studies.

Keywords: Glenoid, Version, CT scan, Coracoid tip-inferior glenoid tubercle distance

INTRODUCTION

Glenoid component loosening, and failure remain the most common complication of shoulder arthroplasty. Proper glenoid baseplate positioning and fixation remain the key for implant stability, outcome, and long-term implant survival.[1] Optimal baseplate positioning follows a proper insertion of the glenoid guide wire with appropriate version and inclination. This has been a challenge due to the complex scapular geometry, and limited intraoperative view of the scapula.[2] Awareness of detailed glenoid morphometry is crucial for prosthetic positioning.[3] The anatomical glenoid orientation shows great patient-specific variability.[4] Although, patient-specific instrumentation and computer-assisted navigation have improved the precision of implant positioning, these technologies are associated with high costs, and long production times.[5] However, accurate preoperative planning with surgeon's experience remains the corner stone for a successful surgery. Detecting the deepest vault region of glenoid facilitates baseplate direction to the region with the maximum bone stock.

Friedman et al originally described the most popular method for version measurement depending on the axial slice at coracoid tip on the two-dimensional (2D) computed tomography (CT) scan. Subsequent studies relied upon either midaxial level or coracoid tip level for version calculation, with no consensus upon the exact level to estimate version at.[6,7] Recently, vault version method evolved as an alternative for glenoid version assessment.[8] No consensus exists regards the precise glenoid level for version assessment, whether at midaxial or coracoid tip level, and if those values are identical or not. Additionally, there is not much data in literature concerning the deepest point of glenoid vault and its proximity to anterior and inferior glenoid surfaces. Thus, we aimed in this study to report glenoid version values at all levels including midaxial and coracoid tip levels, utilizing two different methodologies (Freidman method, vault version method). Additionally, detecting deepest glenoid vault point and how much distant this point from anterior and inferior glenoid aspects.

METHODS

This research has been approved by the institutional research board of the authors' affiliated institution in line with the principles of the Declaration of Helsinki. Academic approval was obtained from the legal person responsible for these samples after they were donated by their families after passing away. Their identity was not disclosed. In addition to the pledge to preserve the bone samples while performing this research and return them to the legal responsible for them (anatomy department related to the authors' same institution). This study was conducted at Mansoura university hospital at the period between April 2021 to July 2022. Sixty dry, unpaired scapulae related to skeletally mature dead individuals (paired scapulae were not available) were included in our study. Thirty-two scapulae belonged to right side and 28 to left side. Bones with clear and intact features with no deformity were included, whilst fractured and deformed ones were excluded. CT scan with 1.25 mm-thick-glenoid slices was performed, taking the advantage of the of CT workstation (GE Optima CT520 16 slice). Two-dimensional cuts were taken parallel to scapular spine on coronal view to obtain standardised axial cuts in all specimens (Figure 1). The obtained Digital Imaging and Communication in Medicine (DICOM) data were analysed using image J program software. Glenoid version was measured at all cuts by two methods: Friedman and vault version methods.[6,8] Then, version was compared at midaxial and coracoid tip levels. Moreover, all 2D axial cuts for each scapula were further divided into nearly three equal parts corresponding upper, middle, lower glenoid thirds. Version of all slices in each third were summed and their average was calculated and compared to those of middle and lower thirds. Both measurement methods defined glenoid line as a line connecting the anterior and posterior glenoid rims. Scapular axis was defined as a connecting line between the tip of the medial scapular border and the glenoid line center in conventional method.[9] Version by conventional method was the angle between glenoid line and the line perpendicular to scapular axis (Figure 2). In vault version method, the measurement landmarks were based within the glenoid endosteal vault. An isosceles triangle was pictured within the medial end of endosteal vault (Figure 3), a line was then drawn from medial corner bisecting this triangle symmetrically.[8] A perpendicular (line B) against this bisector was drawn; this line was defined as the line of neutral version at which the actual glenoid version will be measured off from. A parallel line to the glenoid endosteal face (line A) was finally drawn and the angle at which this line bisected the line of neutral version was measured. Angle was defined retroverted if glenoid posterior margin was medial to the neutral version line. Two evaluators (A.E, A.A) independently assessed all measurements. Statistical significance between the two methodologies regarding version at both midaxial and coracoid tip levels was evaluated. Coracoid tip-inferior glenoid tubercle distance was calibrated in centimetres (cm) using sliding Vernier calliper, that represented the distance between two lines, one cutting coracoid tip and another cutting inferior glenoid tubercle, all lines were aimed parallel to scapular spine (Figure 4). The vault depth was measured on all axial cuts as a perpendicular line from glenoid endosteal face midpoint to endosteal wall (Figure 5), the cut with largest measurement (widest) was identified, and distance from that level to most inferior glenoid aspect was documented. We also measured the depth on all coronal cuts (Figure 6). Similarly, distance from the widest cut to anterior glenoid aspect was documented. Thus, how far the deepest glenoid point from anterior and inferior glenoid aspects was reported.

Statistical analysis

Statistical analysis and data interpretation were fed to the computer and analysed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Quantitative data were described using median (minimum and maximum) for non-parametric data and mean, standard deviation for parametric data after testing normality using Shapiro-Wilk test. Mann Whitney and Kruskal Wallis tests were used for difference significance between two and three groups respectively, difference was considered significant when $p<0.05$.

RESULTS

As demonstrated in (Table 1), the average age for included specimens was 44.63±9.1 years. Males represented 68.3% of cases, and 31.7% for females. The mean versions were 7.1±3.3º and 6.2±2.7º at coracoid tip and midaxial levels using Friedman method with no significant difference in between ($p=0.8$). also, comparing versions of upper, middle, and lower thirds also revealed non-significant differences except between upper and lower thirds (p=0.04).

Table 1: Demographic data for included cases.

Parameters	Observations N (%)	
Age (years)	Mean±SD (44.63±9.1)	
	(20-30)	8 (13.3)
	(30-40)	13 (21.7)
	(40-50)	20 (33.3)
	(50-60)	19 (31.7)
Gender	Male	41 (68.3)
	Female	19 (31.7)

With vault version method, significant difference was noted on comparing version at coracoid tip and midaxial levels. Mean versions were 18.2±10.6º and 8.9±6.8º at coracoid tip and midaxial levels. Also, significant difference was evident on comparing mean version of upper, middle, and lower thirds, except between middle and lower thirds (p=1). Statistically significance was evident between the two methodologies when comparing version at coracoid tip level (p<0.001), while, at midaxial level, there was no significant difference in version (p=0.5) detailed measurements were tabulated (Tables 2, 3).

Table 2: version values at coracoid tip and midaxial levels using friedman and vault version methods.

Measurement method	Coracoid tip	Midaxial	P value
	Value (Mean±SD)		
Friedman method	18.2º±10.6º	6.3º±2.7º	0.77
Vault version method	18.17º±10.62'	9.22º±3.4'	<0.001*

*indicates statistically significant difference

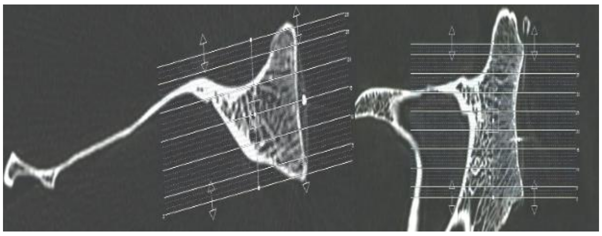

Figure 1: standardized method of CT scan scouts.

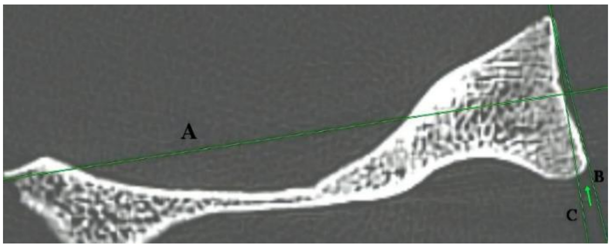

Figure 2: Friedman method of glenoid version measurement. A-scapular axis, B-glenoid plane line, C-perpendicular to scapular axis, green arrow point to version angle between lines B and C.

The mean coracoid tip-inferior glenoid tubercle distance was 3.5±0.5cm, whilst the midaxial level was distant from inferior glenoid. by average 1.8±0.2 cm. The mean vault widest depth of largest value (maximum depth on all axial cuts) was 2.2±0.4 cm (range: 1.5-2.9 cm). Average distance from previously determined widest cuts to glenoid inferior aspect was 8.1±5.3 mm (range: 1.3-17.5 mm). The mean widest vault depth (maximum depth on all coronal cuts) was 2.2±0.3cm (range: 1.7-2.6 cm). Average distance from previously determined widest cuts to anterior glenoid margin was 14.6±2.9 mm (range: 8.8-20 mm).

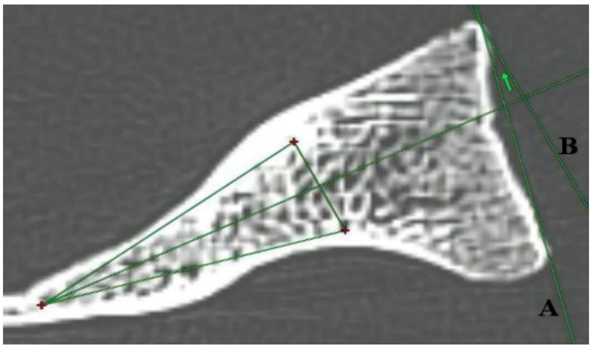

Figure 3: vault version method, green arrow refers to the version angle, green arrow point to version angle between lines A and B.

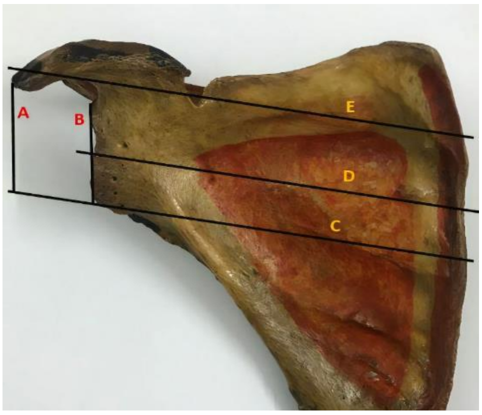

Figure 4: A: Coracoid tip-inferior glenoid tubercle distance, B: glenoid plane, E: scapular spine, D: parallel line cutting mid-glenoid plane, C: parallel line cutting inferior glenoid tubercle.

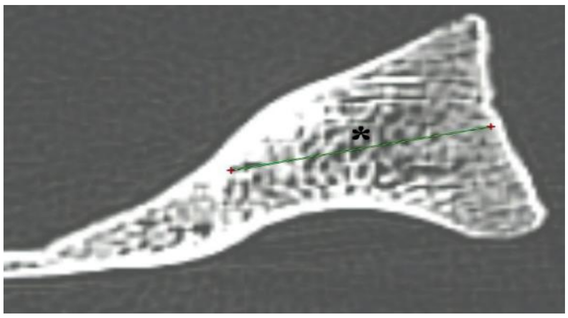

Figure 5: (*)-vault depth on 2D axial cut.

Table 3: version measurements of upper, middle, and lower glenoid thirds using friedman and vault version methods.

Measurement site	Friedman method		Vault version method	
	Value (Mean±SD)	P value	Value (Mean±SD)	P value
Upper third	6.65º±3.063º	P=0.12	17º±8.2º	P<0.001*
Middle third	6.29º±2.79º	P1=0.6	10.08º±5.37º	P1<0.001*
Lower third	5.47º±2.76º	P2=0.04* P3=0.15	10.08º±5.37º	P2<0.001* P3=1

P: Difference between upper, middle, and lower thirds, P1: between upper and middle thirds, P2: between upper and lower thirds, and P3: between middle and lower thirds. *indicates statistically significant difference.

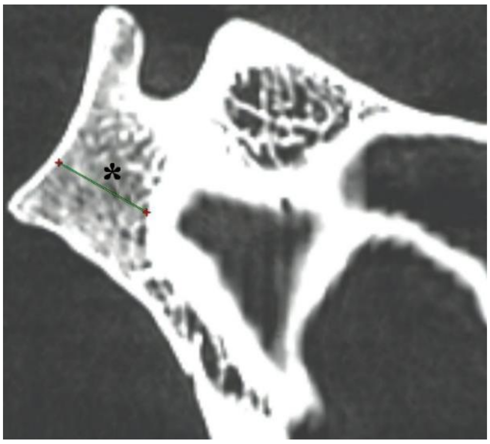

Figure 6: (*)-vault depth on 2D coronal cut.

DISCUSSION

Most studies have reported normal glenoid version around 0°, slightly anteverted sometimes and retroverted under 10° often.[10,11] Version alteration usually impact shoulder mechanics leading to instability, arthropathy, and loosening of glenoid component of arthroplasty.[12,13] Thus, striving for and judgement of version during arthroplasty is always recommended. Version might be dissimilar when compared on different glenoid levels. Friedman et al initially assessed version at or just below coracoid tip level with axial cuts However, other studies took advantage of the midaxial slice for measurement regardless the coracoid tip position.[6]

To the best of our knowledge, there is no consensus regards version measurement at which level, and as coracoid morphology and its tip position are non-identical among individuals, we studied coracoid tip positional relation to mid-glenoid and inferior glenoid aspects. Version was measured and compared by two known methodologies (Friedman, vault version methods) at all glenoid levels in 60 dry human scapulae. This study utilized a standardized measurement method using same CT machine, program, same examiner, slicing technique parallel to scapular spine after having all scapulae positioned inside CT machine with spine coincide with gantry angle of CT beam. The glenoid is known to be AP twisted. Version measurement value is influenced by many variables that alter scapular orientation as patient position in scanner and slice settings orientation, and examiner's measurement practice. Coronal and sagittal scapular rotation may alter version by about 12°.[14] This study revealed no significant difference on comparing version at midaxial level to coracoid tip level using Friedman method (p=0.8), however, a significant difference was noted (p<0.001) with vault version method.

The mean Coracoid tip-inferior tubercle distance was 3.5±0.5 cm. Whilst, midaxial point was distant by mean of 1.8±0.2 cm from inferior glenoid tubercle. It is important to determine regular intervals for version measurements to define a reliable gradient of version change. Use of anatomical landmarks only enables to describe a profile of variation and not a precise gradient as we have no information on the interval in-between. Taking the consideration of this positional variability of anatomical landmarks among individuals, midaxial slice utilization might be more precise for measurement, accounting for a more specific identifiable level. With the benefit of Friedman method, no significant difference in version was noted among upper, middle, and lower glenoid parts, except between upper and lower thirds (p=0.04). In contrary, vault version method revealed significant differences (p<0.001) among all parts except between middle and lower thirds. Similarly, previous studies revealed significantly larger values with vault version method in both normal and arthritic shoulders when compared to Friedman method.[8,15] This disparity in version values among different parts might be explained by the fact that glenoid is AP twisted which impacted conventional method results, while vault version eliminated the scapular body effect.[8]

Familiarity with glenoid anatomy might be beneficial for implant companies to mimic, as the profile of version variation of glenoid components on a craniocaudal axis is not reproduced yet in shoulder arthroplasty field, fitting more to native glenoid anatomy should be considered in future glenoid component designs. Vault version method could be beneficial for operative planning as it does not depend on the medial scapular border, useful for baseplate implantation, and easily applicable in fractured and malunited scapula. Unfortunately, it might be hard to use after arthroplasty as vault dimensions were obscured with metal artifact making it hardly obvious. The distance from widest axial cut to inferior glenoid margin was

8.06±5.34mm, additionally, the distance from widest coronal cut to anterior glenoid aspect was 14.56±2.96mm. Matsen et al demonstrated a point marked 13 mm anterior to posterior glenoid rim and 19 mm superior to inferior glenoid rim to be site of glenoid guidewire insertion prior to glenoid baseplate implantation during reverse shoulder arthroplasty.[16] We relied on most anterior and inferior glenoid rims and their relation to the estimated maximum vault depth on coronal and axial planes depending on the fact that degenerative wear initially attacks posterior glenoid, also, inferior aspect is crucial in arthroplasty. Accurate identification of the widest region on both planes could easily guide rigorous guide wire placement on setting of shoulder arthroplasty with subsequent sound base plate implantation.

Limitations

Limitations of this study were evident in the limited number of included scapulae. Additionally, paired scapulae were not available, it would be more beneficial being compared to their pair utilizing both measurement methods. Further future studies on larger number of scapulae comparing arthritic and non-arthritic ones will be more convenient. Unfortunately, paired scapulae were not available in this study, it would be more convenient to compare their pair utilizing each measurement methodology finding difference in between.

CONCLUSION

Glenoid version varies from one individual to another. Glenoid version at coracoid tip and midaxial levels are not the same. Vault method for measurement could be as suitable method for preoperative planning in patients with scapular body fractures and deformities. Correlation of preoperative version values with intraoperative situations might be studied in future studies.

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