The Effect of Radiographic Beam Angle on Acromiohumeral Interval: 3D-CT Analytic Study

Worawit Ongbumrungphan MD*,
Waraporn Srikhum MD**, Bancha Chernchujit MD*

** Department of Orthopedics, Faculty of Medicine, Thammasat University, Pathumthani, Thailand*
*** Department of Radiology, Faculty of Medicine, Thammasat University, Pathumthani, Thailand*

Background: *An acromiohumeral interval (AHI) narrower than 7 mm measured on AP shoulder radiographs has been considered pathology and strongly indicative for rotator cuff tears. No study to date has investigated the effect of radiographic beam position on acromiohumeral interval (AHI) measurement.*
Objective: *To study the AHI measurement on conventional radiographs compared with 3D computed tomography (3D-CT) scans and the effectiveness of tilted CT images in physician-performed AHI measurement.*
Material and Method: *Twenty-eight patients were measured the AHI on conventional radiographs. The same measurement was performed on 3D-CT image tilted in coronal plane -15 degree, 0 degree (Baseline), +15-degree, +30-degree and +45-degree views. For baseline 3D-CT scan, the image position was set as 30 degrees medial and 10-degree downward tilts.*
Results: *The mean AHI on conventional radiographs (8.8±2.4.mm) is significantly more than the AHI on 3D-CT image (7.10±1.5 mm, p = 0.002). The AHI on conventional radiographs and baseline 3D-CT image showed significant moderate to high correlation (r = 0.647, p<0.001). The upward 3D-CT angle affected the AHI significantly (p = 0.002).*
Conclusion: *The AHI measurement on conventional radiographs is significantly higher than 3D-CT scan, with moderate to high correlation. The different position of the CT image tilts affected the AHI measurements.*

Keywords: *Shoulder, Acromiohumeral interval, AHI, Computed tomography, Radiographic measurements*

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Acromiohumeral interval (AHI) defines as distance between dense cortical bone at the inferior aspect of the acromion and subchondral lamina of the humeral head. Normal AHI interval is about 7-14 mm(1-4). Knowledge of the AHI interval is important because the interval less than 7 mm has been considered to be pathologic condition and strongly suggests a large rotator cuff tear, which the likelihood of successful outcome after the repair is reduced(3,5,6). Some studies have shown that narrowing of the AHI is associated with rotator cuff muscle degeneration(6-10). The assessment of the AHI using standardized anteroposterior radiographs is a reliable and reproducible method of measurement(11-13).

Abduction in the scapular plane and flexion of the shoulder joint have been reported to reduce the AHI, possibly resulting in subacromial impingement(14-16). Fehringer et al(17) conducted a study to determine AHI, even in healthy shoulders, small changes in arm position and radiographic beam orientation affect the AHI in radiographs.

For conventional radiographs, fine-tuning adjustment was made individually by the x-ray technician that had an effect on AHI measurement. No study to date has investigated the effect of radiographic beam position on AHI.

The author hypothesized that relatively changes in radiographic beam tilt may affect physician-performed AHI measurements on conventional radiographs.

The purpose of this study was to compare the measurement of AHI on conventional radiographs and 3D-CT images in different angles. We implied that changing of the 3D-CT angles are reflected the different radiographic beam positions.

Material and Method

After obtaining institutional review board approval, the authors retrospectively cohort-evaluated the patients with shoulder problems presented at our

Correspondence to:
Ongbumrungphan W, Department of Orthopedics, Faculty of Medicine, Thammasat University, Pathumthani 12120, Thailand.
Phone: +66-2-9269999, Fax: +66-2-9269744
E-mail: worawit_md@hotmail.com

orthopedic shoulder outpatient clinic between January 2008 and January 2013. The study population consisted of 28 patients (14 male, 14 female) who underwent conventional radiography and 3D-CT scans of the shoulders. Data were collected retrospectively from the institution's electronic database. Imaging criteria for inclusion were conventional anteroposterior (AP) radiograph of the shoulder with the arm in neutral position and 3D-CT scans of the ipsilateral shoulder. Exclusion criteria, were patient with previous operations on the affected shoulder and imaging evidence MRI or clinical history of rotator cuff tear.

Acromiohumeral distance was measured electronically on a PACS workstation (Synape, Read version 361, Fugi image Devices). On conventional radiographs, the AHI was defined by the distance between two parallel lines: The first line was drawn through the sclerotic line at the undersurface of the acromion, and the second was tangential to the humeral head. The distance between the two parallel lines, representing the shortest distance between humerus and acromion, was recorded as the AHI (Fig. 1). The same measurements were performed by reviewer on 3D-CT images in different angles. The images were angled 15 degree downward, 0 degree baseline), and 15, 30 and 45 degree upward on workstation (Fig. 2).

The baseline image position on 3D-CT scan was set as 30-degrees medial and 10-degree downward tilts, which approximated the routine shoulder AP radiographic position.

Subject characteristics were described using descriptive statistics, including frequencies and percentage for categorical variables. Continuous variables were reported as means with standard deviation. Association of the AHI level compared the mean in changing the angles by using the repeated measure One-way ANOVA. It also compared the AHI mean in conventional radiographs and AHI in baseline 3D-CT images by an independent sample t-test. For all tests performed, p-value <0.05 was considered as denoting statistical significance. The statistical software SPSS, version 16.0 was employed for all the analyses performed.

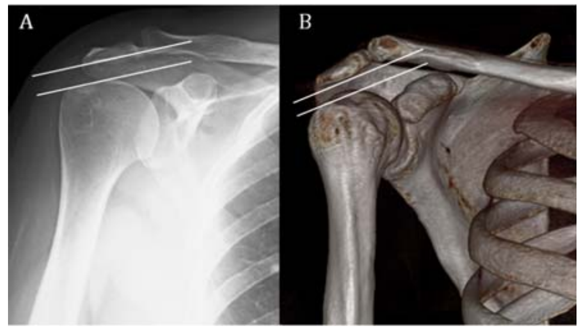

Fig. 1 A) Measurement of acromiohumeral interval on conventional radiographs. The first proximal line is placed upon the sclerotic line, representing the ''roof'' at the undersurface of the acromion. The second line is drawn parallel to the first tangentially to the most superior point of the humeral head. B) Likewise, on computed tomography scans. The respective distance between the 2 lines represents the acromiohumeral interval.

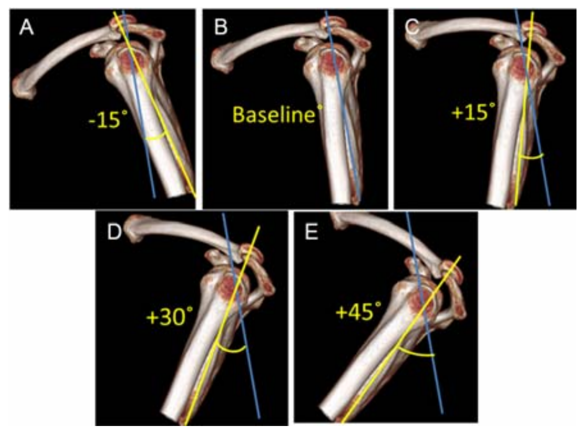

Fig. 2 Illustration of data analysis showing bone reconstructions from CT in 3D reconstructed. The bone positions tilt in coronal plane -15 degree (A), Baseline (B), +15 degrees (C), +30 degrees (D) and +45 degrees (E).

Table 1. Demographic data

Gender	n (%)	Age; mean $\pm$ SD
Male	14 (50)	32.5 $\pm$ 11.8
Female	14 (50)	51.9 $\pm$ 13.0
Total	28 (100)	41.9 $\pm$ 15.7

Results

Acromiohumeral Interval measurements

Demographic data were displayed in Table 1. The mean acromiohumeral interval was 8.8 mm (range, 4.5-14.8 mm; SD, $\pm$2.4 mm) on the conventional radiographs and 7.10 mm (range, 4.82-10.4 mm; SD, $\pm$1.5 mm) on baseline 3D-CT image. The mean of AHI on radiographs was significantly higher than AHI on baseline CT (p = 0.002).

The AHI on radiographs and on baseline 3D-

CT images showed moderate to high correlation and significantly (r = 0.647, p<0.001) (Fig. 3).

Association between the 3D-CT scan angles image and acromiohumeral interval

The means of the AHI measurements on the angled CT images at -15, baseline, +15, +30 and +45 degrees were 6.9±1.5, 7.1±1.5, 6.9±1.7, 6.5±1.5 and 6.1±1.6, respectively. The upward 3D-CT angle was significantly affected the AHI (p = 0.002) (Fig. 4).

Discussion

The purpose of this study was to measure AHI on plain radiographs compared with 3D-CT scans and the effectiveness of the tilted CT images in physician-performed AHI measurement on 3D-CT image, which are implied the effect of different radiographic beam orientations in AHI measurements on conventional radiographs. AHI measurements are of special clinical interest in rotator cuff pathology. A decreased AHI on AP radiographs was defined as the most reliable radiographic finding in rotator cuff tear[1,14,15,18]. For conventional radiographs, fine-tuning adjustment was made individually by the x-ray technician who effected the AHI measurements.

The authors found moderate to high correlation between the AHI measured on conventional radiographs and that measured on baseline 3D-CT image (r = 0.647, p<0.001). Conversely, the study by Werner et al[18], that the AHI measured on conventional AP radiographs correlated poorly with the AHI acquired from CT scans[17]. The possible explanation is in our study we set baseline 3D-CT scan as 30-degree medial tilted and 10-degree down ward tilted, which approximately to the routine shoulder, AP radiographic position.

Our results indicated that the AHI on conventional radiographs is more than AHI on baseline 3D-CT image (mean ± SD = 8.8±2.4 and 7.1±1.5, respectively, p<0.001). This finding confirms the results reported by Saupe et al[6]. Therefore, the position of the patient has shown influence on the AHI measurements, according to whether the patient was upright (as commonly used for conventional non-trauma imaging of the shoulder) or supine (as commonly used for CT scans)[19]. The lack of gravity is believed to be responsible for the smaller AHI measurements in the supine position[19]. Furthermore Fehringer et al[17] conducted a study to determine whether positional changes of the arm and radiographic beam could affect the AHI in AP radiographs. Alterations of the AHI in

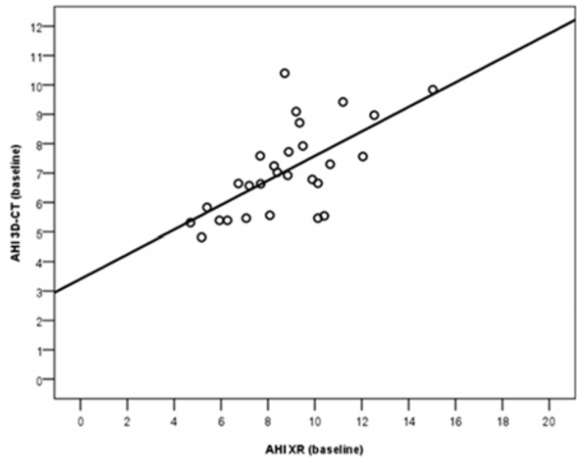

Fig. 3 Linear regression plot for acromiohumeral interval (AHI) values measured on conventional radiography (XR) and baseline 3D-CT image. The correlation values were moderate to high.

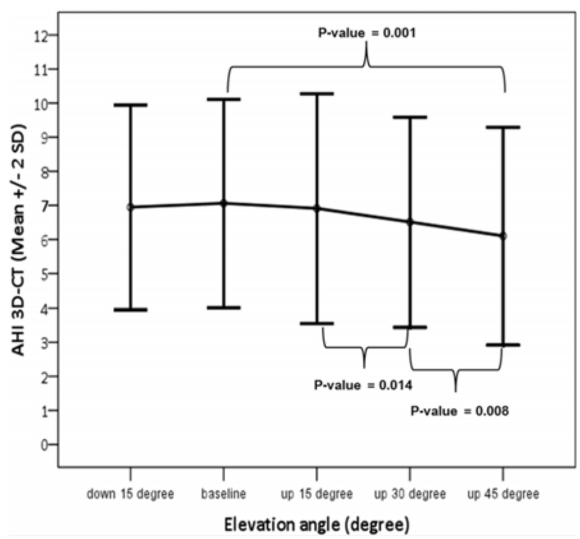

Fig. 4 Mean and standard deviation of AHI measured in tilt of radiographic beam position on 3D-CT image (-15, 0, +15, +30, +45 degree).

relation to glenohumeral motion have primarily been reported for scaption[20]. In addition, it has been theorized that differences in AHI could also be based on the position of the patient during motion exercises (seated, standing, or supine) and gender[20].

However, no previous study has reported the affect in tilted radiographic beam and the change in AHI on coventional radiographs. The authors found that the tilted CT images in different angles, which could represent different position of radiographic beam, had an affect in the AHI measurements. Upward angled 3D-CT images showed significantly effected on the AHI as compared to the baseline images (*p*-value = 0.002). These findings indicate the importance of the radiographic beam position.

Limitations of this study include the number of patients was relatively small; a larger population is needed for validation. Second, the radiographic measurements were performed by single reviewer and lastly this study could not be evaluated the different radiographic beam orientation directly and implied by changing the CT images angles, which may not represent exactly.

In conclusion, our results allow moderate to high correlation between AHI measured on conventional radiographs and that measured on baseline 3D-CT image. Application of CT scan measurement was smaller than the corresponding conventional radiographs. The different angled CT images affected the AHI which could represent the effect of radiographic beam tilt. Future studies are necessary to more validate this Hypothesis and learn how to obtain more accurate AHI measures from conventional radiographs.

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Potential conflicts of interest

None.

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ศึกษาการเปลี่ยนแปลงของค่า acromiohumeral interval กับการเอียงลำแสงเอกซ์เรย์โดยใช้ 3D-CT scan

วรวิทย์ อึ๊งบำรุงพันธุ์, วราภรณ์ ศรีขำ, บัญชา ชื่นชูจิตต์

ภูมิหลัง: *การศึกษาในปัจจุบันยังไม่มีข้อมูลที่ชัดเจนว่าการเปลี่ยนแปลงการเอียงลำแสงเอกซ์เรย์ส่งผลกระทบต่อ AHI หรือไม่*

วัตถุประสงค์: *1) เพื่อศึกษาค่า AHI จากภาพรังสีธรรมดาเทียบกับค่าที่วัดจากเอกซ์เรย์คอมพิวเตอร์สามมิติ, 2) เพื่อศึกษาว่าการเปลี่ยนแปลงการเอียงลำแสงเอกซ์เรย์มีผลต่อค่า AHI หรือไม่*

วัสดุและวิธีการ: *ผู้ป่วยที่เข้าร่วมการศึกษาจำนวน 28 ราย จะได้รับการวัดค่า AHI จากภาพรังสีธรรมดาเทียบกับค่าที่วัดจากเอกซ์เรย์คอมพิวเตอร์สามมิติ ในท่าเอียงทำมุม -15, 0, +15, +30, +45 องศาตามลำดับ โดยที่มีการเอียงมุมของเอกซ์เรย์คอมพิวเตอร์สามมิติให้อยู่ในแนวระดับก่อน*

ผลการศึกษา: *ค่าเฉลี่ย AHI ที่วัดจากภาพรังสีธรรมดาและค่าที่วัดจากเอกซ์เรย์คอมพิวเตอร์สามมิติ คือ 8.8±2.4 มิลลิเมตร และ 7.10±1.5 มิลลิเมตร ตามลำดับ ซึ่งมีความแตกต่างกันอย่างมีนัยสำคัญ (p-value = 0.002) ค่า AHI ที่วัดจากภาพรังสีธรรมดามีความสัมพันธ์กับค่าที่วัดได้จากเอกซ์เรย์คอมพิวเตอร์สามมิติในระดับปานกลางถึงสูง (r = 0.647)*

สรุป: *ค่าเฉลี่ย AHI ที่วัดจากภาพรังสีธรรมดาสูงกว่าค่าที่วัดจากเอกซ์เรย์คอมพิวเตอร์สามมิติอย่างมีนัยสำคัญ การเปลี่ยนแปลงการเอียงลำแสงเอกซ์เรย์มีผลต่อค่า AHI*