Reliability of the radiographic views in supine position for evaluation of displaced midshaft clavicle fracture length

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Abstract
Purpose: To analyze the agreement of the displaced midshaft clavicle fracture length measurement between each of the supine radiographic position (chest anteroposterior (AP), both clavicle AP, and 20° cephalic tilt clavicle AP view) and computed tomography (CT) scan of the clavicle. Furthermore, the inter- and intraobserver reliability of each radiographic position was analyzed. Methods: Prospective cross-sectional study was performed with patients diagnosed with displaced midshaft clavicle fracture treated conservatively. Three views of radiographs and CT scan of clavicle were obtained in supine position after informed consent. The measurement of fractured clavicle length was done by three observers at the time and after 4 weeks interval. Results: Thirty-three patients (25 males and 8 females), with a mean age of 45, were recruited. The agreement between each of the radiographic measurement and CT scan was good. The interobserver reliability was moderate to good for radiographic measurement. The highest intraclass correlation coefficient (ICC) of 0.80–0.81 was shown between the 20° cephalic tilt and the CT scan, followed by the both clavicle AP (0.75–0.77) and the chest AP (0.69–0.75), respectively. There was an excellent intraobserver reliability for all of the radiographic measurement with the ICC 0.92–0.99. Conclusion: The supine radiographs could be a useful option to measure the displaced midshaft clavicle fracture length. The recommended view was the 20° cephalic tilt clavicle AP view in supine position to best evaluate the fractured clavicle length.

Keywords
clavicle length, fracture clavicle length, midshaft clavicle fracture, supine radiograph, supine X-ray

Introduction
Fractures of clavicle are common in adults. Most of these fractures occur within the middle third of the clavicle and often showed some degrees of displacement. Treatment of the displaced midshaft clavicle fracture has evolved from nonoperative treatment to selected indication for open reduction and internal fixation. Conservatively treated displaced midshaft clavicle fractures may lead to poor functional outcome if the overall clavicle length was 15–20 mm shorter than the normal contralateral clavicle. The shortening was reported to cause reduced shoulder strength, persistent pain, or altered scapular kinematics. Therefore, modern literature have been recommended to use shortening more than 2 cm as...
a relative indication for surgical management of the displaced midshaft clavicle fractures.9,10

Open reduction and internal fixation of the displaced midshaft clavicle fractures may risk the patient for complications, including infection, implant-related complication, or damage to adjacent neurologic and vascular structures.11 If shortening of the displaced midshaft clavicle fracture more than 2 cm is to be used as an indication for surgery, reliable technique of measurement is required to correctly categorize patients who will benefit from surgery.

Up until now, the radiographic measurement of the displaced midshaft clavicle fracture length has been inconclusive regarding the position of the patient and the projection and the magnification of the radiographic beam. From our knowledge, there has been no study with consistent protocol to control all those abovementioned factors, which could be in part of the error in the studies.5,12,13 The upright radiographs might not be a suitable option to predict the position at healing of the fracture in conservatively treated patient with an arm sling, as the effect of gravity is eliminated.

The computed tomography (CT) scan is widely accepted as a reference standard for measuring the length of the bone. However, it has to be done in a supine position. We hypothesized that the X-rays taken in the supine position may better correlate to the CT scan more than in previous reported upright position. The purpose of our study was to evaluate the agreement and reliability of the clavicle length measurement from three views of plain radiographs in supine position and the CT scans in an acute fracture with controlled situation.

Materials and methods

Ethical approval was obtained from Srinakharinwirot University Ethics Committee prior to the commencement of this study (reference number SWUEC/EC-241/2560). Patients diagnosed with closed acute displaced midshaft clavicle fracture were recruited between June 2018 and June 2019 for a prospective cross-sectional study. Inclusion criteria were aged more than 18 years old, without pathological fracture, and were planned to treat conservatively after patient counseling. Exclusion criteria were associated fracture that affected the measurement of fractured clavicle length, unable to do the CT scan within the same day of injury, and has other clear indication to undergo surgery. Informed consent was obtained from all patients prior to the radiographic evaluation.

Three radiographs, including chest AP, both clavicle AP, and 20° cephalic tilt both clavicle AP view, were taken in supine position. The beam was shot 100 cm away from the cassette (Figure 1). The CT scan of both clavicles was obtained within the same day of the traumatic event. All of the fractured clavicles were measured in Picture Archiving and Communication System (PACS)14 by three independent investigators, including a fellowship-trained shoulder surgeon, a sports medicine fellow, and an orthopedics resident. All the data were recorded in millimeters. Four weeks later, the same investigators were asked for a second investigation to provide intraobserver reliability (Figure 2).

The measurement protocol was set to use for all radiographs and CT scan. Firstly, the medial landmark, which was the point between supero- and inferomedial corners, was identified. Then, the point between supero- and inferolateral ends of the bone was also identified. The distance between two points was measured for clavicle length (Figure 3).

The primary outcome was the agreement of measured clavicle length between the radiographs and CT scans. The secondary outcome was to assess inter- and intraobserver reliability of the radiographic measurements of displaced midshaft clavicle fracture length from each view.
Using the below formula in MedCalc (MedCalc Statistical Software version 16.4.3), the required sample size in detecting an effect of $\alpha$ 0.05 and $\beta$ 0.2 was 33 patients.\textsuperscript{15} The standard deviation (SD) was analyzed from the study of Smekal et al.\textsuperscript{5}

\[
\begin{align*}
    n = & \left( \frac{\alpha^2 + \beta^2}{1 - \beta/\alpha} \right) \left( \frac{1}{t_{1-\alpha/2}^2/n - 1} + \frac{t_{1-\alpha/2, n-1}^2 S_D^2}{2(z_{1-\alpha/2} S_D - \delta)^2} \right)
\end{align*}
\]

The demographic data (age, sex, severity of trauma, and AO Foundation/Orthopaedic Trauma Association classification) were analyzed by mean and percentage. The agreement between the measurement from each of the radiographic position and CT scan was assessed by Bland–Altman plot analysis. This system is based on the mean and SD of the difference between ratings of the same subject. The dashed line represents the upper limit of agreement for each parameter (average $\pm 1.96 \times$SD).\textsuperscript{16} The intraclass correlation coefficient (ICC) two-way mixed model on an absolute agreement was used to analyze the inter- and intraobserver reliability.\textsuperscript{17} The values of the ICC can range from 0 to 1 with a higher value indicating better reliability. An ICC of less than 0.40 was considered as poor, 0.40–0.59 as fair, 0.60–0.74 as good, and 0.75–1.00 as excellent. All analyses were conducted in SPSS 22 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).

**Results**

During the study period, 45 patients were diagnosed with acute displaced midshaft clavicle fracture. Six patients were excluded due to which unable to do the CT scan within the same day of injury. Twelve patients were excluded because they had other indications to treat surgically, including one patient with potential risk for skin perforation, two patients with open fractures, two patients with floating shoulder, and seven patients with severe angulation. Thus, 33 patients satisfied the criteria for inclusion identified as 25 male and 8 female patients with a mean age of 45 (range 18–88) years. Twenty-three patients (69.7%) were injured by high-energy trauma (motorcycle or car accident) and the remaining 10 patients (30.3%) were injured by low-energy trauma (bicycle accident or falling).
For the AO/OTA classification by consensus, there are 13 patients (39.4\%) with 15.2A, 16 patients (48.5\%) with 15.2B, and 4 patients (12.1\%) with 15.2C (Table 1).

### Agreement

The agreement of the measured clavicle length between each radiographic position and CT scan was calculated and presented in Bland–Altman plot. All of the radiographic measurements were shown good agreement to the CT scan (Figure 4).

### Reliability

For the interobserver reliability of each radiographic measurement, all of the ICC between each of them and CT scan were shown moderate to good reliability (Table 2).

Accordingly, the ICC of the measurement between the time point and after the 4-week interval of each radiographic position also shown excellent intraobserver reliability (Table 3).

### Discussion

It is still controversial whether the shortening of the midshaft clavicle fracture is associated with clinical outcomes. Recently, Malik et al. showed no significant association between fracture shortening and nonunion rates or shoulder outcome scores in displaced midshaft clavicle fractures managed nonoperatively.\(^{18}\) While the others reported lower functional outcomes with shortening related to reduced shoulder strength, persistent pain, or altered scapular kinematics,\(^{19,20}\) some studies have recommended early operative management of shortening and displaced midshaft clavicle fracture especially with more than 2 cm shortening due to the higher rates of nonunion and symptomatic malunion.\(^{21–23}\)

Shortening of the clavicle could be estimated by several techniques, including clinical measurement with tape and radiographic measurement from plan X-rays or CT scan.\(^{6,24,25}\) Since there was no recommended standard imaging to be used to evaluate the displaced midshaft clavicle fracture length, many studies used the CT scan to be the reference of the measurement due to the precision of the bony structure evaluation.\(^{5,12,26}\) Unfortunately, a number of studies did not mention about the patient position while taking the radiographs, which could be affected on the evaluation compared to the CT scan.\(^{5,12,13}\) Archer et al. reported a weak correlation between X-ray and CT scan measurement of acute displaced midshaft clavicle fracture shortening.\(^{12}\) However, their findings may result from the inconsistent patient positioning. The X-rays were taken in the upright position while all CT scans were obtained with the patient supine. Our study controlled all these variables, including patient positioning and radiographic protocols. The finding from Backus et al. also confirmed that the shortening was increased on the upright compared to the supine radiographs.\(^{13}\)

Apart from the upward pull of the sternocleidomastoid muscle on the medial clavicle fragment, the effect of gravity pulling down the lateral half of the clavicle is the main reason of fracture displacement. Malik et al. recommend that upright radiographs should be done to evaluate the maximal displacement of the midshaft clavicle fracture.\(^{27}\) However, we did not find any report related to the evaluation of the radiographs in an upright position with an arm sling. Usage of the arm sling is the mainstay of conservative treatment because it causes less patient discomfort and fewer complications than with the figure-of-eight bandage.\(^{28}\) Wearing the arm sling might also reduce the gravity effect by supporting the elbow. Some observational studies tried to investigate the effect of shoulder devices on shoulder subluxation after stroke. They found that wearing the arm sling could immediately reduce an acromiohumeral interval.\(^{29–31}\) For the same reason, a supine position X-ray, which has no effect of the gravity, may provide a true length of the midshaft clavicle fracture if we decide to treat the patients with the arm sling as the treatment continues by nonoperative approach.

Smekal et al. investigated the reliability of three X-rays view, including 15° cephalad tilted of the clavicle, a 15° cephalad tilted anteroposterior of the shoulder, and a
posteroanterior thorax. They found that the agreement with CT measurements was highest for the measurements on posteroanterior thorax radiographs. However, they did not mention about the position of the patient for X-rays.

From our results, we compared three views of radiographic measurement in supine position to the CT scan, which was also done in supine position. The results have shown good agreement from Bland–Altman analysis. This

Table 2. The ICC between each of the radiographic measurement and CT scan.4

|               | Chest AP | Both clavicle AP | 20° cephalic tilt |
|---------------|----------|-----------------|------------------|
| Observer 1    | 0.72     | 0.77            | 0.81             |
| Observer 2    | 0.69     | 0.76            | 0.81             |
| Observer 3    | 0.75     | 0.75            | 0.80             |

AP: anteroposterior; ICC: intraclass correlation coefficient. *p < 0.05.

Table 3. The ICC of each radiographic measurement at the time point and at the 4-week interval.5

|               | Chest AP | Both clavicle AP | 20° cephalic tilt |
|---------------|----------|-----------------|------------------|
| Observer 1    | 0.92     | 0.98            | 0.98             |
| Observer 2    | 0.94     | 0.97            | 0.98             |
| Observer 3    | 0.99     | 0.99            | 0.98             |

ICC: intraclass correlation coefficient. *p < 0.05.

Figure 4. Bland–Altman plot shows a good agreement between each of the radiographic measurement and CT scan. (a) Average of chest AP and CT scan, (b) average of both clavicles AP and CT scan, and (c) average of cephalic tilt clavicle AP and CT scan. AP: anteroposterior; CT: computed tomography.
could be interpreted that the supine radiographs might be used to evaluate the shortening of the displaced midshaft clavicle fracture. Therefore, the patient who was suffered with the injury or extreme pain from the deforming gravitation force may not be necessary to take the radiograph in the upright position.

Furthermore, the highest interobserver reliability of the supine radiographic measurement was the 20° cephalic tilt clavicle AP view. There were only two measurements (6.1%) that differ more than 2 cm in the group of 20° cephalic tilt clavicle AP. We thought that this happened due to the fact that the 20° cephalic tilt beam can eliminate the overlap of the thoracic cage and show the clavicle in profile.

The intraobserver reliability of radiographic measurement in supine position also showed excellent reliability at the 4-week interval. Therefore, we recommend to use the supine 20° cephalic tilt clavicle AP view in supine position to evaluate the displaced midshaft clavicle length.

The strength of our study is the prospective design with consistent protocol for radiographic exams in all patients. We also confirm the reproducibility of our results by doing the intraobserver reliability at the 4-week interval, which is adequate to reduce the recall bias of the observers. However, there were some limitations of this study. Firstly, the protocol that fixed the distance from the tube to the cassette at 100 cm might be affected in some patients with obesity or underweight who have different clavicle position due to their bodies' morphometry. Second, as the shape of the clavicle is complex s-shaped, it may prevent the bone from being positioned perpendicular to the radiograph cassette. Series of more than one radiographic view may help to eliminate this problem. Lastly, in conservatively treated clavicle fracture, patient will spend most of the time in the arm sling in an upright position. Moreover, the materials of the sling may lose their quality overtime. Therefore, the supine radiographs may not be the best in predicting the final clavicle length after healing. However, we plan to report the final clavicle length and the outcome of our patients with the analysis of the shortening of the clavicle in the near future.

Conclusion
Radiographs taken in a supine position could be a reliable tool to measure the displaced midshaft clavicle fracture length. The 20° cephalic tilt clavicle AP view in supine position is recommended to best evaluate the fractured clavicle length with high inter- and intraobserver reliability.

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