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ORIGINAL ARTICLE

Revisiting the surgical indication of mid-shaft clavicle fractures: Clavicle asymmetry

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ABSTRACT

Objectives: The aim of the study was to investigate whether clavicular symmetry was a valid assumption and to assess the factors that could predict clavicular asymmetry.

Patients and methods: Between January 2021 and April 2021, a total of 100 consecutive patients (61 males, 39 females; mean age: 63.6±15.5 years; range, 27 to 94 years) whose both clavicles were adequately seen on chest computed tomography (CT) were retrospectively analyzed. Clavicular lengths were measured on three-dimensional (3D) reconstruction of chest CTs by two independent orthopedic surgeons on two separate occasions. The longest distance passing the straight line between the most lateral part of the clavicle at the acromioclavicular joint and the most medial point of the clavicle on the sternoclavicular joint was given as the clavicle length after adjusting tilt of convertible 3D CTs. Clavicular length difference was calculated by subtracting the short clavicle's length from the long clavicle's length. Patients' age and sex were noted. The calculated clavicular length differences were assigned into three groups: ≤5 mm, >5 mm and ≤10 mm, and >10 mm.

Results: The mean right and left clavicle lengths were 13.9±1.3 cm and 14.1±1.2 cm, respectively ($p<0.001$). A total of 29 patients (29%) had >5 mm clavicle asymmetry and six patients (6%) had more than 10 mm clavicular length difference. Age, sex, and clavicular length were not associated with the clavicular length difference.

Conclusion: Our study results showed that 29% of the patients had >5 mm clavicular length asymmetry. The clavicular symmetry may not be a valid assumption in the decision making for the surgical treatment of mid-shaft clavicle fractures; thus, this assumption may lead to maltreatment. More factors that can predict clavicle asymmetry should be investigated in future studies.

Keywords: Clavicle fracture, clavicle length, clavicle shortening, conservative treatment, surgical treatment.

Clavicle fractures are relatively common injuries accounting for 2.6 to 4% of fractures in adults.[1] These fractures particularly occur in patients below 50 years of age. Approximately 75 to 80% of the clavicle fractures are located in the mid-shaft region.[2] Distal clavicle fractures occur after falling on the open arm or directly on the shoulder and constitute approximately 15 to 20% of all clavicle fractures.[3]

Despite being a prevalent injury, the ideal treatment modality remains unclear for mid-shaft clavicle fractures. Traditionally, conservative treatment was the hallmark of the treatment of mid-shaft clavicle fractures.[4] However, conservative treatment has been reported to cause a greater percentage of symptomatic malunion and nonunion, up to 15%, compared to surgical treatment.[5-7] On the other hand, surgical treatment has also been reported to have similar outcomes with conservative treatment at one year follow-up, but has higher complication rates, particularly implant-related problems.[8,9]

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Major indications for surgical treatment of mid-shaft clavicle fractures are open fractures, severe displacements causing skin perforation or neurovascular injuries.[10] In addition, clavicular shortening over 15 to 20 mm, floating shoulder, or polytrauma are relative indications for surgery.[11] Clavicular shortening has been reported to be associated with a higher percentage of nonunion and biomechanical changes, as well as unsatisfactory functional outcomes following conservative treatment.[6,12,13] Therefore, recent algorithms for the treatment of mid-shaft clavicle fractures have shifted toward surgical treatment, if clavicular shortening exceeds 15 to 20 mm.[14,15]

Clavicular lengths can be measured by using a standardized 15-degree tilted radiograph, 15-degree up-tilted anteroposterior panorama radiograph, posteroanterior thoracic radiograph, three-dimensional (3D) computed tomography (CT), or by simple tape method.[16] Following the measurement of clavicular lengths, clavicle shortening can be calculated by comparing the fractured clavicle length with the uninjured contralateral side[17] or it can be measured by calculating the overlap distance of fractured clavicle segments.[6,18] Posteroanterior chest radiograph suggested as the standardized method to determine length differences in acute clavicular fractures.[16] Measurements according to the contralateral side assume both clavicles are symmetric and have the same lengths. However, the measurements based on clavicular symmetry may lead to undertreatment or overtreatment of clavicle fractures, if clavicles are not symmetric.

In the present study, we hypothesized that clavicles were not identical in length and clavicular symmetry was not an accurate assumption. We, therefore, aimed to investigate whether clavicular symmetry was a valid assumption and to assess the factors that could predict clavicular asymmetry.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Karabük University Faculty of Medicine, Department of Orthopedics and Traumatology between January 2021 and April 2021. Thoracic CT scans obtained for any reason in our institution were reviewed. Patients whose both clavicles were adequately seen on chest CT were included. Patients aged below 18, having a spinal deformity, and having a history of previous clavicle injury during interview were excluded. Finally, a total of 100 consecutive patients (61 males, 39 females; mean age: 63.6±15.5 years; range, 27 to 94 years) were included in the study.

Measurements were performed on the 3D reconstruction of chest CTs by two independent orthopedic surgeons on two separate incidences and there were at least two weeks between each measurement. Observers were trained in measurement methodology prior to the study to improve the standardization. The most lateral part of the clavicle at the acromioclavicular joint and the most medial point of the clavicle on the sternoclavicular joint was defined. The longest distance passing the straight line between these points were given as clavicle length after adjusting tilt of convertible 3D CTs. The superior surface of the clavicles was examined on 3D CTs during measurements.[9] Observers noted the maximal clavicular length during the measurements for both right and left clavicles (Figure 1). Clavicular length difference was calculated by subtracting the short clavicle's length from the long clavicle's length. Patients' age and sex were obtained from hospital registry notes. The calculated clavicular length differences were assigned into three groups (≤5 mm, >5 mm and ≤10 mm, >10 mm).[19]

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD) for continuous variables and in number and frequency for categorical variables. Distribution of variables was measured with the Kolmogorov-Smirnov test. Continuous variables were analyzed using the Student t-test, paired t test, or analysis of variance (ANOVA), when appropriate. Categorical variables

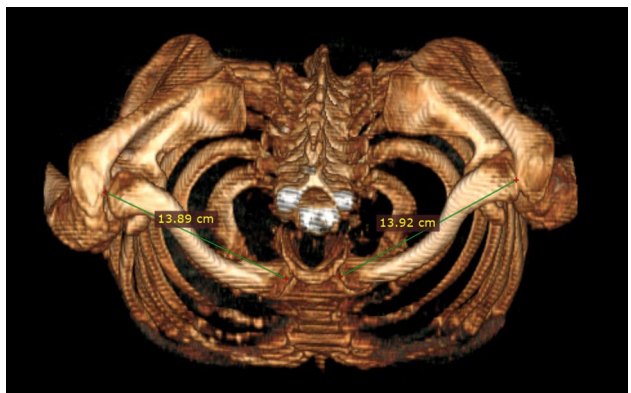

FIGURE 1. Measurement of the clavicular length on 3D computed tomography from the superior surface of clavicle.

were analyzed using the Pearson chi-square test. Linear correlation analysis was performed with the Pearson test. Inter- and intra-rater reliabilities were assessed using the two-way random effects intra-class correlation coefficient (ICC). A priori power analysis was performed for the primary outcome (mean clavicular length). Utilizing an alpha value of 0.05, beta of 0.80, and a standardized Cohen's d value of 0.4 the estimated sample size required at least 100 clavicles per cohort or 200 total clavicles to obtain 0.8 actual power. A *p* value of <0.05 was considered statistically significant.

RESULTS

The mean right and left clavicle lengths were 13.9±1.3 cm and 14.1±1.2 cm, respectively (p<0.001). The mean clavicular length difference was 4.0±3.3 (range, 0 to 20.5) mm.

Male patients had longer clavicle lengths than female patients on both right (14.6±1.1 cm and 12.8±0.8 cm, p<0.001) and left (14.7±1.1 cm and 13.1±0.7 cm, p<0.001) side. There was no statistically significant difference in the mean clavicle length difference between male (3.2±0.4 mm) and female (4.4±0.5 mm) patients (p=0.386). There was no statistically significant difference in asymmetry groups between the sex and age distribution (Table I).

Age had no correlation with the clavicular length difference (r=0.079, p=0.438). Clavicular lengths on right (r=0.134, p=0.184) and left (r=0.056, p=0.582) side were not correlated with the clavicular length difference.

A total of 29 patients (29%) had >5 mm clavicle asymmetry. Besides, six patients (6%) had more than 10 mm clavicular length difference. Both

TABLE I
Clavicular asymmetry according to sex and age

	≤5 mm (n=71)			>5 mm and ≤10 mm (n=23)			>10 mm (n=6)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age			63.3±16.4			62.7±13.5			70.3±10.1	0.550
Sex										0.859
Male	44	72.1		13	21.3		4	6.6		
Female	27	69.2		10	25.6		2	5.1		

SD: Standard deviation.

TABLE II
Intra-rater reliability of the observers

	Right clavicle				Left clavicle			
		95% CI				95% CI		
	ICC	Lower limit	Upper Limit	*p*	ICC	Lower limit	Upper Limit	*p*
1st rater	0.953	0.930	0.968	<0.001	0.947	0.922	0.965	<0.001
2nd rater	0.984	0.976	0.989	<0.001	0.985	0.977	0.990	<0.001

CI: Confidence interval; ICC: Inter-class correlation coefficient.

TABLE III
Inter-rater reliability of the observers

	Right clavicle				Left clavicle			
		95% CI				95% CI		
	ICC	Lower limit	Upper Limit	*p*	ICC	Lower limit	Upper Limit	*p*
1st measurement	0.941	0.913	0.961	<0.001	0.932	0.899	0.954	<0.001
2nd measurement	0.964	0.947	0.976	<0.001	0.969	0.954	0.979	<0.001

CI: Confidence interval; ICC: Inter-class correlation coefficient.

intra-rater and inter-rater reliability were excellent (Tables II and III).

DISCUSSION

Clavicle shortening is a frequent problem in patients sustaining mid-shaft clavicle fractures.[20] However, there is not an ideal method to quantify the clavicular shortening. A common technique that has been described to quantify the clavicular shortening on anteroposterior chest radiograph assumes that both clavicles are identical and symmetric.[17] In the current study, we investigated whether clavicular symmetry was a valid assumption by using 3D reconstruction of chest CTs and we showed that 29% of the patients had clavicle asymmetry more than 5 mm. It is not clear how often the contralateral clavicle length is utilized in the decision making for surgical indications for clavicle fractures by orthopedic surgeons; however, we believe that the knowledge supporting clavicle asymmetry in our study may decrease its usage.[21]

The importance of clavicular shortening on functional outcomes is controversial. There are several studies reporting that clavicular shortening is not associated with poorer functional outcomes;[9,22] however, some authors have reported worse outcomes with clavicular shortening.[3,12] Although these studies have used variable measurement methods including conventional radiographs and CT, they all compared fractured clavicles with uninjured side assuming both clavicles are symmetric. Considering the 29% clavicular asymmetry exceeding 5 mm in the current study, the contradictory results regarding the influence of clavicular shortening on functional outcomes may be due to the initial inaccurate assumption of defining both clavicles are symmetric.

Despite the limited number of studies in orthopedics literature regarding clavicle asymmetry,[19,23,24] it has been well studied in anthropology, anatomy, and forensic medicine literature.[25-27] Mays et al.[26] evaluated clavicle morphometry in medieval skeletal assemblage and reported that left clavicles were longer than right clavicles. Abdel Fatah et al.[25] examined 505 individuals' clavicles from the William McCormick Clavicle Collection with CT scan and reported that left clavicles were longer than the right clavicles. Cunningham et al.[23] and Hoogervorst et al.[19] demonstrated that left clavicle was longer than right clavicle with their CT studies on healthy individuals. Our findings regarding the clavicle length difference are consistent with the previous literature.

Cunningham et al.[23] were the first to question the surgical indication, clavicle shortening, for clavicle mid-shaft fractures assuming clavicle symmetry and suggested that 28.5% of the individuals had clavicle asymmetry more than 5 mm. In addition, they reported a mean of 4.25±3.8 mm clavicle length difference between both sides. Then, Hoogervorst et al.[19] confirmed the clavicle asymmetry and reported that 30% of the patients had clavicle asymmetry >5 mm. In the current study, 29% of the patients showed clavicle asymmetry and our study is supportive of these former studies. Given the previous literature and the current study, the measurement method assuming clavicle symmetry to calculate clavicle length difference may cause errors in the treatment of mid-shaft clavicle fractures and should be used meticulously.

Sex, side, and hand dominance are the factors that have been reported to be associated with the clavicular length.[19] However, factors related to the clavicular length difference or clavicular asymmetry have not been clearly investigated in the literature. In the current study, we assessed the potential parameters such as age, sex, and clavicle length that can be related to clavicle length difference, and have found no association with these factors and clavicular length difference. To the best of our knowledge, these parameters have firstly been studied in terms of clavicular length difference. It is not clear why some patients have clavicular asymmetry and some do not. We may argue that a future advanced model with multiple potential influencing factors to predict clavicle asymmetry would be beneficial.

Apart from measuring clavicular shortening according to the contralateral clavicle, some methods have been described using the principles of fragment overlap on plain radiographs.[6,18] These overlap measurement methods have the advantage of not being influenced by clavicle asymmetry. However, Thormask et al.[28] compared the reliability of overlap measurement techniques with the measurements based on the contralateral clavicle. The overlap measurement techniques had poor reliability compared to the measurement method based on the contralateral clavicle. Therefore, the theoretical advantage of these overlap methods may not be translated to clinical practice due to their poor reliability. Further research is needed to establish a reliable method for calculating clavicular length difference.

Nonetheless, there are some limitations to the current study. First, it has a retrospective design. Although patients with previous clavicular injuries

were excluded, there may be still some patients with clavicular injuries that they did not remember. Second, this is a regional single-center study; therefore, the results cannot be generalized to the entire population. Third, in the setting of a clavicle fracture, it is atypical to measure for clavicular shortening on chest CT and it is questionable to measure the appropriate clavicular lengths. However, we attempted to investigate the presence of clavicle asymmetry and question the usefulness of clavicular shortening in decision making for mid-shaft clavicle fracture surgery. Although we adjusted the tilt of 3D CTs prior to measurements, 2D length measurements were performed on 2D scans of 3D reconstructions. Although we included two observers for the reliability analysis, more observers would be more feasible.

In conclusion, our results showed that 29% of the patients had >5 mm clavicular length asymmetry. The clavicular symmetry may not be a valid assumption in the decision making for the surgical treatment of mid-shaft clavicle fractures while calculating the amount of clavicular shortening; thus, this assumption may lead to undertreatment or overtreatment. More factors that can predict clavicle asymmetry should be investigated in future studies.

Ethics Committee Approval: The study protocol was approved by the Karabük University Non-Interventional Clinical Research Ethics Committee (date: 01.10.2021, no: E.67419). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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