RESEARCH ARTICLE

Proximity of Vital Structures to the Clavicle: Comparison of Fractured and Non-fractured Side

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Abstract

Background: Previous anatomic and radiological studies have described the relationship of the clavicle to major neurovascular structures in healthy subjects. We were curious about this relationship in patients with a clavicle fracture and if it is different from non-fractured clavicles.

Methods: We retrospectively identified all patients with a clavicle fracture between July 2001 and October 2013 in two level 1 trauma centers. Patients aged 18 years or greater with an acute unilateral clavicle fracture and a chest CT scan in the supine position displaying both clavicles and the complete fracture were included. Seventy patients were available for study. The distance was measured from the fracture site and from the closest clavicular cortex to the closest major artery, major vein, and inner surface of the thoracic cavity. CT data was evaluated in OsiriX DICOM viewer software with the use of three-dimensional Multiplanar Reconstruction.

Results: Compared to the fractured side, the clavicle was significantly closer to the artery and vein on the non-fractured side ($P<0.001$ and $P=0.0025$ respectively). There was a significant difference in the median distance of the fracture site to the artery, vein, and inner surface of thoracic cavity between the different types of fractures ($P<0.001$). A post-hoc comparison showed significant differences in all distances between fracture types, except for the distance of proximal third compared to middle third fractures to the closest artery ($P=0.41$). There was no significant difference in distance when the arm is up overhead compared to down by the side of the body in computed tomography (CT) scans.

Conclusions: A fracture of the clavicle changes the relationship of the clavicle to major vital structures. The minimum distance of the clavicle to the closest artery and vein is significantly less on the non-fractured side, compared to the fractured side.

Keywords: Clavicle, Computed tomography, Distance, Fracture, Vital structures

Introduction

Clavicle fractures are common injuries, and patients with displaced fractures are increasingly offered surgery (1, 2). Neurovascular structures are rarely directly injured by a clavicle fracture, but are at risk with operative treatment (3-7). Previous anatomic and radiological studies have described the relationship of the clavicle to the parietal pleura and major neurovascular structures in healthy subjects, based on the distance from reference points on the clavicle (5, 6, 8). This relationship has not been assessed in patients with clavicle fractures and the distance from the fracture site to vital structures has not been reported. We were curious about the relationship of the clavicle to vital structures in patients with a clavicle fracture and if it is different from the relationship in non-fractured clavicles.

The primary null hypothesis of this study was that there is no difference in minimum distance of the clavicle to vital structures between the fractured and non-fractured side among patients with a unilateral clavicle fracture. Secondary analyses evaluated if there is a difference in distance of the fracture site to vital structures between different types of fractures and if there is a difference in distance when the arm is up overhead compared to

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down by the side of the body in computed tomography (CT) scans.

Materials and Methods

Subjects

In a retrospective search in our billing database, 1647 patients with a clavicle fracture were identified between July 11th, 2001 and October 15th, 2013 in two level 1 trauma centers. The International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM) (code 810.0x for closed fracture, and 810.1x for open fracture) and Current Procedural Terminology (CPT) (code 23500 for closed treatment of clavicle fracture; without manipulation, 23505 for closed treatment of clavicle fracture; with manipulation, and 23515 for open treatment of clavicle fracture) were used to search the billing data. A CT scan was performed in 244 patients, of which 87 were unilateral CTs of the shoulder or arm, and 157 were bilateral. Inclusion criteria were: patients aged 18 years or greater with an acute unilateral clavicle fracture and a CT scan in the supine position displaying both clavicles and the complete fracture. Seventy patients met the inclusion criteria and were available for study.

Both arms of the patient were at the side of the body in 19 of the CTs, only the left arm was overhead in 24, only the right arm was overhead in 12, and both arms were overhead in 15. The arm of the fractured side was overhead in 16 patients. There were 49 men and 21 women in this study, with an average age of 47 years, range 18-90 years (SD 21) [Table 1]. Institutional Review Board approval was acquired.

Methods of measurement

To determine the anatomical relationship on CT images, a research fellow identified the clavicle, sternoclavicular joint, acromioclavicular joint, first rib, subclavian artery, subclavian vein, brachiocephalic trunk, brachiocephalic vein, aorta, and thoracic cavity [Figure 1]. The following were measured: the distance from the proximal or distal clavicle fracture site (whichever was closest) to the major artery (the subclavian artery, brachiocephalic trunk or aorta), major vein (the subclavian vein or brachiocephalic vein), and inner surface of the thoracic cavity [Figure 2]. If the clavicular cortex was closer to the artery, vein, or inner surface of the thoracic cavity at another place than the fracture side, this distance was measured as well, calling it the minimum distance. The minimum distance was measured on the non-fractured side too. The fractures were classified according to Allman as Group I (middle third) in 45 patients, group II (distal third) in 19 patients, and group III (proximal third) in 6 patients (1).

The measurements were made using OsiriX DICOM viewer software version 5.7.1 32-bit (OsiriX Foundation, Geneva, Switzerland) on a MacBook Pro with Retina display (Apple, Inc., Cupertino, California) using the CT – Bone view. With the use of three-dimensional Multiplanar Reconstruction (3D MPR), additional images were created from the original plane in either the coronal, sagittal, or oblique plane. The window level and amplitude were freely altered to complete the measurements.

In order to assess the interobserver reliability, two research fellows made independent measurements of 10 scans. The intraclass correlation coefficient (ICC) was substantial, with an average of 0.97 for the minimum distance at the non-fractured side, 0.95 for the minimum distance at the fractured side, and 0.90 for the distance from the fracture site to the vital structures.

Analysis

A post-hoc power analysis showed that 70 patients provide 99.97% power to detect a 2.53 mm difference in minimum distance of the clavicle to the artery between the fractured and non-fractured side (α=0.05).

Parametric dependent variables were compared using the paired t-test. Non-parametric data were compared using the Wilcoxon signed rank test, the Wilcoxon rank sum test, and the Kruskal-Wallis test. Post-hoc

Table 1. Demographics (n=70)

	N	%
Sex		
Female	21	30
Male	49	70
Side of injury		
Left	25	36
Right	45	64
Type of fracture		
Proximal third	6	8.6
Middle third	45	64
Distal third	19	27
Position arms		
Both arms down	19	27
Only left arm up	24	17
Only right arm upz	12	34
Both arms up	15	21
Fractured side up	16	23

Table 2. Minimum distance of the clavicle to vital structures (n=70)

	Non-fractured side		Fractured side		*P*
Vital structure	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)	*P*-value
Closest artery	4.58	4.01	7.11	3.66	<0.001
Vital structure	Median (mm)	Range (mm)	Median (mm)	Range (mm)	*P*-value
Closest vein	0.70	0.00-6.11	1.70	0.00-11.65	0.0025
Inner surface thoracic cavity	6.49	0.00-14.67	5.57	0.00-22.61	0.90

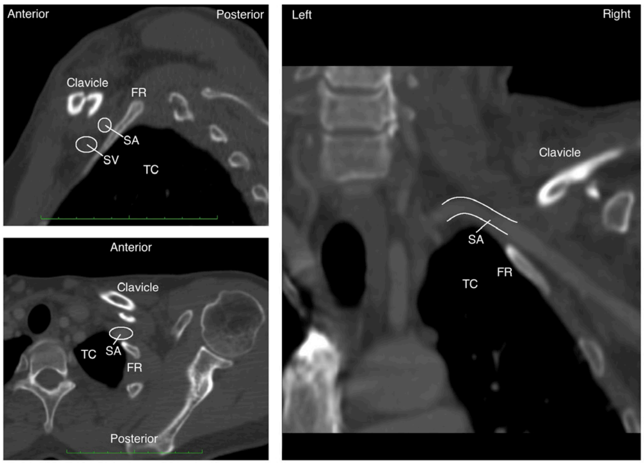

Figure 1. Sagittal (top left), transverse (bottom left), and coronal plane (right) in three-dimensional Multiplanar Reconstruction (FR, first rib; SA, subclavian artery; SV, subclavian vein; TC, thoracic cavity).

comparisons were done applying the Wilcoxon rank sum test for individual pairs of groups adjusted for multiple testing by Bonferroni correction. Baseline characteristics of study patients were summarized with frequencies and percentages for categorical variables, and with mean and standard deviations for continuous variables.

The interobserver reliability was measured with the ICC. Interpretation of the ICC values was carried out according to the guidelines proposed by Schrout and Landis as follows: 0.00-0.10 virtually none, 0.11-0.40 slight, 0.41-0.60 fair, 0.61-0.80 moderate, 0.81-1.00 substantial (9). Statistical analysis was conducted using Stata version 12.0 software (StataCorp LP, College Station, Texas).

Results

Compared to the fractured side, the clavicle was significantly closer to the artery and the vein on the non-fractured side (P<0.001 and P=0.0025 respectively). The vein was the structure closest to the clavicle (average 0.70 millimeters when non-fractured) [Table 2].

There was a significant difference in the median distance of the fracture site to the artery, vein, and inner surface of the thoracic cavity between the different types of fractures (P<0.001). A post-hoc comparison showed significant differences in all distances between fracture types, except for the distance of proximal third compared to middle third fractures to the artery (P=0.41). On

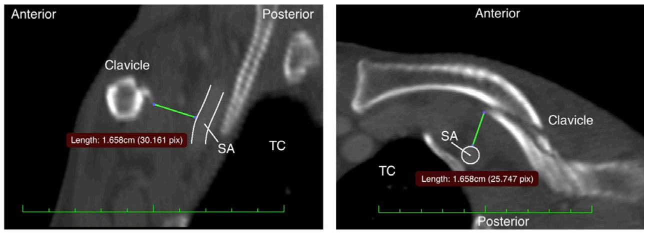

Figure 2. Distance of the fracture site of a type I fracture to the subclavian artery (SA) in an altered window level of the sagittal plane (left) and coronal plane (right). (TC, thoracic cavity).

average, the vein was the closest structure to the fracture site in fractures of the proximal and middle third, and the artery was the closest structure to fractures of the distal third of the clavicle [Table 3].

The artery and vein were further away from the fracture site with the arm over the head, the inner surface of the thoracic cavity was closer to the fracture site, and the minimum distance of the clavicle cortex to all three structures decreased, but the differences were not significant with the numbers available [Table 4, 5].

Discussion

A fracture of the clavicle changes the relationship of the clavicle to vital structures. The minimum distance from the clavicle to the artery and vein is significantly less on the non-fractured side, compared to the fractured side. When comparing the different fracture types, the median distance of the fracture site of proximal third fractures is smallest to the inner surface of the thoracic cavity and vein, and the median distance of the fracture sites of proximal and middle third fractures are smallest to the artery.

There are several limitations to consider. First, measurements were based on CT scans displaying the resting position of the clavicle fracture. These measurements could differ from fracture deformity at the time of injury. Second, the CT scans were not standardized. There was a range of slice thickness between 1 and 5 millimeters, with most scans having a thickness of 2.5 millimeters—unavoidable in a retrospective study (10). Third, the number of patients with proximal third fractures was small as these fractures are uncommon (1, 3). Finally, the spatial relationship between the clavicle and brachial plexus was not considered in this study, because neural structures can easily be confused with fat, connective tissue, or vessels on CT scans (11).

Werner et al. assessed the distance from fracture lines marked on the midshaft of non-fractured clavicles to the subclavian artery, vein and brachial plexus in cadaveric

Table 3. Distance of fracture site to vital structures for fracture types

	Proximal third (n=6)		Middle third (n=45)		Distal third (n=19)		
Vital structure	Median (mm)	Range (mm)	Median (mm)	Range (mm)	Median (mm)	Range (mm)	*P*-value
Closest artery	13.57	9.41-25.47	12.38	0.32-37.09	35.50	20.86-61.75	<0.001
Closest vein	2.54	1.61-6.77	12.35	1.10-35.96	44.91	24.15-65.04	<0.001
Inner surface thoracic cavity	15.39	9.88-19.56	21.75	10.46-50.68	43.55	18.54-68.10	<0.001

Table 4. Distance of fracture site to vital structures for arm position in CT

	Arm down (n=54)		Arm up (n=16)		
Vital structure	Median (mm)	Range (mm)	Median (mm)	Range (mm)	*P*-value
Closest artery	15.42	0.33-51.81	16.91	8.09-61.75	0.43
Closest vein	14.76	1.10-56.97	21.65	1.61-65.04	0.47
Inner surface thoracic cavity	28.18	10.46-68.10	21.34	26.45-58.61	0.24

Table 5. Minimum distance of the fractured clavicle to vital structures for arm position in CT

	Arm down (n=54)		Arm up (n=16)		
Vital structure	Median (mm)	Range (mm)	Median (mm)	Range (mm)	*P*-value
Closest artery	6.56	0.33-24.21	6.06	0.32-14.45	0.80
Closest vein	1.82	0.00-11.65	1.53	0.00-10.60	0.43
Inner surface thoracic cavity	6.30	0.00-22.61	6.26	1.20-18.44	0.85

specimens (6). Compared to our results, the reported distances from the midshaft fracture lines to the subclavian artery and vein were larger (18.9 millimeters and 21.1 millimeters, respectively). However, the extensive dissection performed on the cadaveric specimen could have altered the distances, giving a less accurate representation of the clavicle region than our study.

Shina et al. and Lo et al. evaluated the distance from reference points on the posterior cortex of the clavicle to vital structures (5, 8). The distance from the clavicle to the subclavian vein was the smallest at the medial part of the clavicle. Furthermore, the distance to the subclavian artery was smaller for the medial and middle part of the clavicle compared to the distal part. This is in accordance to our findings. However, it was found that the pleural cavity was closest to reference points at the midshaft, whereas we measured the smallest distance to the parietal pleura at the proximal third of the clavicle. Yet, we were not confined to set reference points and found that the smallest distance to the parietal pleura was at the proximal end of the clavicle, a point that was not considered in previous studies.

Other studies assessed the relationship between clavicle and vital structures after anterior and superior plating, and in order to assess safe drilling depths and angles (4, 7). We feel that these studies are beyond the scope of our study, because they tried to stay away from neurovascular structures, thus are not discussed further here.

It is our impression that the upward pull of the sternocleidomastoid muscle causes the medial part of the fractured clavicle to displace superiorly, away from the vessels and pleura (3, 7). It is also possible that fracture hematoma creates more space between the structures and the bone, although this was not clearly visible on CT. There was a downward displacement of the distal fragment towards the pleura and vascular structures, which moved the fracture site closer to the structures. However, this displacement often did not affect the minimum distance, as the proximal end of the clavicle was closer to vital structures than any part distal of the fracture side.

Injury to the pleura and subclavian vessels have—on rare occasion—been ascribed to a clavicle fracture fragment (12-16). This is plausible, but difficult to verify. The rarity of such claims in spite of anatomical proximity indicates that alternative mechanisms of injury should be considered in these exceptional cases. On the other hand, while proximal third fractures are closest to the vein and pleura on average, the minimum distance of the vein and artery to the fracture site was smaller for middle third fractures. Being aware of this wide variety in range when treating fractures operatively could decrease the risk of iatrogenic injury.

Some authors recommend shoulder abduction of 90° as a safety measure during open reduction and internal fixation of a clavicle fracture (5, 6). We found no significant differences in the minimum and median distance between the fracture site and vital structures according to arm position. Therefore, the influence of arm position on the potential for neurovascular injury remains debatable.

The minimum distance of the clavicle to vital structures is greater on the fractured side compared to the non-fractured side. While the median distance of the fracture site to the vital structures differs between fracture types, the minimum distance is similar. Although clavicle fractures are rarely implicated in injury to neurovascular structures, physicians should be aware of the proximity of these structures and the variation between patients, remaining alert when treating clavicle fractures operatively.

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