Clavicular Length: The Assumption of Symmetry

BRIAN P. CUNNINGHAM, MD; ALEX MCLAREN, MD; MICHAEL RICHARDSON, MD; RYAN MCLEMORE, PhD

Recent studies have shown subjectively worse outcomes associated with 15 to 20 mm of clavicle shortening. As a result, more than 15 mm of shortening has become a relative indication for operative management. Various methods to quantify shortening have been described in the literature. All measurement techniques described assume clavicular symmetry to assess clavicular shortening. The goal of this study was to assess the side-to-side variation in clavicle length in uninjured, skeletally mature adults.

Clavicle length in 102 skeletally mature adults (age range, 22-91 years) was measured using computed tomography data. Clavicle length was defined as the distance between the lateral-most point of the clavicle in the acromioclavicular joint and the medial-most point of the clavicle in the sternoclavicular joint. The side-to-side difference in clavicular length was analyzed, and patients were organized into 2 groups: group 1 was symmetric (difference of less than 5 mm), and group 2 was asymmetric (difference of more than 5 mm). Mean difference in clavicle length for all patients was 4.25 ± 3.8 mm (range, 0-23 mm). Clavicular symmetry was found in 73 (71.5%) of 102 patients. The remaining 29 patients had asymmetry greater than 5 mm. Asymmetry greater than 10 mm was found in 7 (7%) of 102 patients. Twenty-eight percent of clavicles were asymmetric, whereas 7% had clinically significant asymmetry that could affect treatment decisions.

This finding calls into question previous methods developed to assess clavicular length in the setting of trauma because of the assumption of symmetry. Further studies are needed to evaluate the effect of hand dominance and pediatric trauma on this observation.

The authors are from Banner Good Samaritan Medical Center (BPC, AM, RM), Phoenix; the Center for Interventional Biomaterials (AM, RM), Arizona State University, Tempe, Arizona; and the Department of Musculoskeletal Radiology (MR), University of Washington, Seattle, Washington. The authors have no relevant financial relationships to disclose.

Correspondence should be addressed to: Ryan Y. McLemore, Banner Good Samaritan Medical Center, 901 E Wiletta St, Phoenix, AZ 85006 (ryan.mcllemore@bannerhealth.com).

doi: 10.3928/01477447-20130222-24

Figure: Axial computed tomography scans of the right shoulder through the sternoclavicular joint (left) and the acromioclavicular joint (right). The medial-most point is marked with a + (left) and the lateral-most point is marked with a dot (right). The coordinates x1,y1,z1 for the medialmost point and x2,y2,z2 for the lateralmost point were determined from the dicom metadata. Dotted lines represent the distance between the points in the 3 axes. The straight line distance between the 2 points was calculated using the 3-dimensional form of the Pythagorean theorem.
Clavicle fractures are common, accounting for 2% to 5% of all fractures and 35% to 45% of fractures of the adult shoulder girdle.1 Middle-third fractures comprise 70% of clavicle fractures.2 Conventionally, clavicle fractures have been managed nonoperatively. However, operative management of displaced midshaft clavicle fractures has recently demonstrated superior outcomes compared with nonoperative treatment.3,4 The absolute indications for operative management of AO type 15-B clavicle fractures are open fractures, fractures where the integrity of the overlying skin is at risk, and fractures associated with neurovascular compromise.5-7 Recent studies have shown subjectively worse outcomes and a higher incidence of pain, functional deficit, and poor cosmetic result with nonoperative management of clavicle fractures that present with 15 mm or more of shortening.8-11 As a result, 15 mm of shortening has become a relative indication for operative intervention.8-11 Various methods to quantify shortening have been described in the literature. Previous studies have recommended determining the preinjury length of the clavicle by measuring the contralateral uninjured clavicle. Various techniques have been described: posteroanterior12 and anteroposterior8,9 chest radiographs, anteroposterior panorama shoulder girdle radiographs,13 two radiographs of the clavicle,14 posteroanterior 15° caudad radiographs,15 and clinical measurements.3,16 The length of the contralateral clavicle has not been validated as an accurate indicator of the preinjury length of a fractured clavicle.

The purpose of this study was to determine the side-to-side difference in clavicle length in adult reconstruction patients who had not sustained a clavicle injury. To the authors’ knowledge, no orthopedic study has evaluated the side-to-side anatomic variation of clavicle length. The authors hypothesized that clavicular length is symmetrical in adults and is not dependent on sex.

**Materials and Methods**

After institutional review board approval, computed tomography (CT) scans of the chests of adult reconstruction patients were collected from a private institution in 2007. Inclusion criteria were (1) the entire length of both clavicles was included in the CT scans, (2) minimum age of 18 years at the time of the scan, and (3) no radiographic signs of clavicular trauma or pathology existed. A total of 130 CT scans were reviewed; 102 scans met the inclusion criteria, and 28 scans were excluded for skeletal immaturity and incomplete imaging of the acromioclavicular joint.

All clavicles were measured using a technique adapted from Smekal et al.13 Clavicle length was defined as the distance between the lateral-most point of the clavicle in the acromioclavicular joint and the medial-most point of the clavicle in the sternoclavicular joint. A single observer (B.P.C.) identified the medial-most point of the clavicle on the slice through the sternoclavicular joint and the lateral-most point of the clavicle on the slice through the acromioclavicular joint. The x-, y-, and z-axis coordinates for the medial-most and lateral-most points were determined from the dicom metadata using Osirix software version 4.0 (Osirix, Geneva, Switzerland) (Figure 1). Clavicle length (L) was then calculated in Excel (Microsoft, Redmond, Washington) using the 3-dimensional form of the Pythagorean theorem:

\[ L = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \]

The side-to-side length difference (LD) between the right and left clavicles was calculated by subtracting the length of the long side (LS) from the length of the short side (SS). The proportional length difference (PLD) between the right and left clavicles was calculated as the length difference (LD) as a percentage of the short side (SS):

\[ PLD = \frac{[(LS - SS) / SS] \times 100}{} \]

Computed tomography measurement of clavicular length was validated by directly measuring an anatomical specimen of a skeletonized (ie, all soft tissue attachments were removed) cadaveric clavicle using calipers (Figure 2). A CT scan was obtained of the anatomic specimen. Clavicle length was determined using the method described above and was subsequently measured by hand using a tape.
measure. The 2 measurements were then compared for accuracy.

Interobserver reliability was determined by having 3 observers identify the medial-and lateral-most points of the right and left clavicles on a subset of 15 CT scans. The 3 observers were trained by providing a brief description of the technique followed by a demonstration of the technique on both clavicles in 1 CT scan. The 15 CT scan subset was selected to bridge the range in observed length difference and was analyzed in random order. Selected patients’ clavicular asymmetry ranged from 7 mm longer on the left to 8 mm longer on the right based on initial measurements. Observers were blinded to scan selection. Clavicular length and side-to-side length difference were determined using the methods described above and compared with the values determined by the primary study observer for those CT scans.

Absolute length difference between sexes was compared using the Mann-Whitney U test. The relationship between length difference and length of the clavicle was evaluated using a Bland-Altman plot. Interobserver agreement between observers was assessed by calculation of intraclass correlation coefficients.17

All statistical analysis was performed using Minitab software version 15 (Minitab Inc, State College, Pennsylvania). Statistical significance for all tests was set at α=0.05.

RESULTS

Mean patient age was 53.6 years (range, 22-90 years). Of the 102 patients, 40 were men and 62 were women. Average clavicle length was 144.7±11.2 mm (range, 135-176 mm for men, 112-153 mm for women) on the right and 146.4±10.6 mm (range, 142-170 mm for men and 119-161 mm for women) on the left. Average side-to-side difference in clavicular length was 4.25±3.8 mm (range, 0-23 mm) (Figure 3). Patients were divided into 2 groups based on the amount of asymmetry present: symmetric (difference of less than 5 mm) and asymmetric (difference of more than 5 mm). These criteria are not intended to be diagnostic, but rather to provide a reference to the proportion of patients and magnitude of asymmetry that may be expected in a similar population. Seventy-three (71.5%) patients were symmetrical, 22 (21.5%) had differences between 5 and 10 mm, and 7 (7%) were asymmetrical. Mean right clavicle length was 144.7±11.2 mm, mean left clavicle length was 146.4±10.6 mm, and mean asymmetry percentage was 2.9%±2.8%. Computed tomography length measurement of the anatomical clavicle specimen (16.1 cm) was in agreement with direct measurement of length measurement using a measuring caliper (16.1 cm) (Figure 2).

No statistical difference existed between men’s and women’s clavicular asymmetry (P=.495). Based on a t-distribution, 40 patients per group provided adequate power to detect a difference as small as 1.8±3.8 mm per group. No relationship existed between clavicle length and length difference as indicated by the Bland-Altman plot (Figure 4). The bias was −1.65 mm, the lower limit of agreement was −12.47, and the upper limit of agreement was 9.1 mm. No predilection existed for which side was longer.

Interobserver reliability was strong, with an intercorrelation coefficient ranging from 0.70 to 0.86, indicating strong agreement. Observed length differences were similar (within 1-2 mm) for all observers.

DISCUSSION

To evaluate clavicular symmetry, the authors measured the length of 102 pairs of clavicles on existing CTs obtained for nontraumatic reasons in adults undergoing clavicle reconstruction. Computed tomography provides the most accurate
An anatomic image relative to other measurement methods. Symmetry was documented in 73 (71.5%) patients, a length difference between 5 and 10 mm was documented in 22 (21.5%), and asymmetry was documented in 7 (7%). This finding suggests that clavicular symmetry may not be an accurate assumption for a meaningful portion of the population. It has been suggested in the forensic literature that side-to-side clavicular asymmetry exists, however, the current study is the first in the orthopedic literature.

This study is unable to comment on the effect of patient history or handedness on clavicular asymmetry, and these questions must be addressed in future studies.

Although no evidence exists on CT scans of prior clavicular trauma, without a detailed patient history previous clavicular trauma cannot be ruled out. It is possible that some variation seen in the current study could have arisen from fractures in early childhood that had healed with no radiographic evidence. Although the study did not elucidate the cause of asymmetry, existing asymmetry due to trauma or developmental pathology would be unknown to the physician treating the fracture. The study did not examine the cause of shortening, but demonstrated that asymmetry exists.

Evaluating the degree of shortening in acute clavicular fractures has become an important component when deciding between operative and nonoperative treatment. Several methods for evaluating clavicular length have been described. Plain radiographs are subject to error secondary to parallax, and although clinical and CT measurements have eliminated parallax, important limitations remain. The challenge of accurately identifying landmarks on physical examination introduces error. The software used in many clinical CT scanners cannot calculate the distance between 2 points across multiple 2-dimensional slices; however, the length between 2 points across multiple slices can be measured from 3-dimensional reconstructions if it is measured on the workstation when the reconstructions are generated. Length cannot be measured from 3-dimensional reconstructions after they are saved unless the reconstruction includes a calibration scale from which to measure. The authors generated the data in this study using metadata from the dicom image files, processed in Osirix, to identify the x-, y-, and z-axis coordinates of the measuring point at each end of the clavicle. Clavicular length was then calculated in Excel using the Pythagorean theorem. The inability of clinical scanners to calculate length across multiple slices was not apparent to the current authors until they asked the radiologists to provide measurements of the anatomic specimen from 2-dimensional slices and 3-dimensional reconstructions that were saved to a specimen file.

All described methods depend on clavicular symmetry to determine the normal prefracture clavicular length. The error between observers for the current technique is 1 to 2 mm based on interobserver reliability. Computed tomography spatial registration is highly accurate.

The amount of acceptable shortening for midshaft clavicle fractures remains controversial, with inconsistent outcomes reported in the literature. Nordqvist et al reported no functional difference in patients with residual shortening more than 15 mm. Ooko et al reported a finding in a retrospective cohort of 41 patients with no association between shortening and outcome. In contrast, multiple studies have demonstrated that nonoperative management of patients with 15 to 20 mm of shortening has been associated with higher rates of nonunion, functional deficits, and lower patient satisfaction. Smekal et al reported that patients experiencing sequelae 2 years after injury without surgery had an average shortening of 6.1% ± 5.2%. Subsequently, 15 to 20 mm has become a relative indication for operative management. The current study identified 2 groups of patients: those with symmetrical clavicles (a difference of less than 5 mm) and those with asymmetrical clavicles (a difference of more than 5 mm). Asymmetry of 10 mm or more is important because it is common to have 5 mm of shortening. In many cases, this would change the treatment from operative to nonoperative or vice versa based on 15 mm of shortening. Displaced midshaft clavicle fractures have a reported average shortening of 12 to 15 mm. Patients with 10 mm or more of anatomic variation could be subjected to operative or nonoperative management based on an apparent shortening of 2 or 25 mm if the contralateral clavicle is used as a reference.

The results of the current study raise concerns regarding the accuracy of using the contralateral clavicle as a reference to determine prefracture length. With 28% of patients having 5 mm or more of anatomic asymmetry, the current methods for evaluation have a significant error potential. A significant limitation of the study is that the handedness of the patients was unknown and could not be determined. Although it has been shown that hand dominance is associated with differences in upper-limb bone mineralization and hand size, its relationship to clavicular asymmetry is unknown. However, it is known that approximately 90% of Americans are right-handed, and if this affected symmetry, it would be expected to cause a shift in the Bland-Altman plot toward the right side (Figure 4). The Bland-Altman plot showed longer clavicles on both sides in similar frequencies, which is inconsistent with hand dominance causing asymmetry.

**Conclusion**

Current techniques used to assess shortening in acute clavicle fractures rely on the assumption of clavicular symmetry. This study determined that 72% of patients have symmetrical clavicles but that 28% have more than 5 mm of asymmetry. Clavicular asymmetry rarely (7% of patients) exceed-
ed 1 cm, and although the reason for this asymmetry is unknown, the clinician should be aware of this potential discrepancy in prefracture clavicular length.

References


