Curvatures and Medullary Canal of the Clavicle Among an Egyptian Population: A three Dimensional Computed Tomography Study

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ABSTRACT

Background: Clavicle is the most frequently fractured bone in human skeleton. Fractures treated non-operatively showed higher rate of non-union or malunion. Operative treatment have superior results over the non-operative treatment, and include two approaches; external fixation or internal fixation. External fixation may be cosmetically displeasing and uncomfortable. Internal fixation is accompanied by a higher rate of cure with lesser complications, however the shape and size of the medullary canal of the clavicle can be a prohibiting factor making the placement of intramedullary devices difficult.

Aim of work: The present work was designed to study the length, the curvatures as well as the dimensions of the medullary canal of the clavicle among Egyptians using three dimensional computed tomography.

Material and Methods: This study was carried on one hundred clavicles. CT scan of the chest with coronal and sagittal reformatting and 3D reconstruction of the clavicle was done.

Results: The length of male clavicles was longer than female clavicles. Left clavicles were shorter than right clavicle in both sexes. The medial as well as the lateral angle of the left clavicle was greater than that of the right clavicle in both sexes. The height and width of the medullary canal of the clavicle were generally greater in males than in females.

Conclusion: Computed tomography imaging has been shown to be an accurate method for describing the anatomy of the clavicle. Data could be used to determine whether the anatomy of the clavicle and its medullary canal were suitable for intramedullary fixation.

Key Words: Clavicle, Anatomy, CT, Intramedullary Fixation.

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INTRODUCTION

The clavicle is the first bone in the body to be ossify, it is also the only long bone that ossify by intramembranous ossification (Ogata and Uhthoff, 1990). The clavicle consists of cancellous bone, enveloped by cortical bone, which is much thicker in the middle 35/ of the clavicle than in the lateral and medial fifths (Andermahr, 2007).

The clavicle serves as the sole bone connecting the axial skeleton to the shoulder girdle through the sternoclavicular joint medially and the acromioclavicular joint laterally. It transmits the weight of the upper limb to the axial skeleton. Its unique and complex shape plays an important role in the stability, movement and cosmetic aspect of the shoulder girdle (Anderson 2003).

The shaft of the clavicle is gently curved and its shape resembles the italic g letter, being convex forwards in its medial two thirds and concave forwards in its lateral third (Standring, 2005).

The clavicle is the most frequently fractured bone in human skeleton, Most of the fractures occur in the shaft of the clavicle which is accordingly the weakest part of the bone (Anderson, 2003).

Historically, midclavicular fractures were treated non-operatively using slings or figure 8 braces, which have a higher rate of either non-union or malunion resulting in shoulder complications (Stanley et al., 1988); (Hill et al., 1997); (Jubel et al., 2003). Clavicular non-union or malunion influences the architecture of
the whole shoulder girdle and the coordination between its elements (Andermahr et al., 2006).

Recent studies have shown that the operative treatment have superior results over non-operative treatment (Mckee et al., 2006). There are two approaches for operative treatment; external fixation or internal fixation. External fixation using plate and screw may be cosmetically displeasing, uncomfortable and irritating for many patients (Wenninger et al., 2013). On the other hand, internal fixation of the clavicle using intramedullary nail is accompanied by a higher rate of cure and lesser complications and is largely considered as the treatment of choice (Jubel et al., 2003); (Wenninger et al., 2013).

Although intramedullary fixation is an effective mode of treatment (King and Ikram, 2011); (Ferran et al., 2010); (Houwert et al., 2012); (Liu et al., 2010), the shape and size of the medullary canal of the clavicle can be a prohibiting factor for the use of intramedullary nail, making the placement of intramedullary devices difficult. If the canal is too small to allow reamers or nails to be inserted, the fixation of the fracture by means of an intramedullary device is impossible. Again absence of an adequate medullary canal at the far medial and lateral sides of the clavicle, causes problems while passing the intramedullary device far enough past the fracture site to give adequate fracture stability (King and Ikram, 2011). Hence it is important to accurately determine the size of the medullary canal of the clavicle before considering intramedullary fixation.

AIM OF WORK

The present work was designed to study the length, the curvatures as well as the dimensions of the medullary canal of the clavicle among Egyptians using three dimensional computed tomography. The study help to verify whether the anatomy of the clavicle and its medullary canal is suitable for intramedullary fixation in treatment of clavicular fractures.

MATERIAL AND METHODS

This study was carried on one hundred clavicles belonging to fifty subjects divided equally into twenty five male and twenty five female and aging between 20-60 years.

Subjects were randomly selected from the patients coming to perform computerized tomography scanning of their chest for different clinical presentation. Patients with congenital malformations of the clavicle, previous fracture or previous surgery of the clavicle were excluded from this study.

• The Device used is Multidetector Computed Tomography 16 detector Toshiba Asteon.

• The patients scanned in the supine position with the arm above the head. Antero-posterior and lateral scanograms were performed.

• The patients were scanned from the level just above the acromion process till the middle of the chest.

• The images were obtained in the axial plane with post processing coronal and sagittal reconstruction.

• Multislice CT scan of the chest with coronal and sagittal reformating and 3D reconstruction of the clavicle was done; (Bernat et al., 2014); (King et al., 2014); (Mathieu et al., 2014).

• Measurements were taken on the 3D images in cranial view to assess the length of the clavicle using the point tracing method (defined as the line which crosses through the center of the clavicle). (Fig. 1)

• Measurements were taken on the 3D images in cranial view to assess the angle between the sternoclavicular end and the shaft (medial angle also called the sternal angle) and the angle between the acromioclavicular end and the shaft (lateral angle also called the acromial angle). The angles were measured by obtaining the angle between two lines drawn tangential to the shaft of the bone (Fig. 2)

• Measurements were taken on the coronal section images to determine the cross sectional dimensions (height and width) of the medullary canal of the clavicle in 3
reference points; in the most medial part, middle part and the most lateral part of the medullary canal.

- The height of the medullary canal was measured by drawing a vertical line that passes from the superior to the inferior limit of the canal in the three reference points (the most medial end, middle part and the most lateral end). (Fig. 3)

- The width of the medullary canal was measured by drawing a line that passes horizontally from side to side inside the canal in the three reference points (the most medial end, middle part and the most lateral end). (Fig. 4)

• Measurements were taken in the axial images to assess the length of the medullary canal; by subtracting the sum of the length at which the canal begins and ends from the total length of the clavicle. (Figs. 5, 6)

RESULTS

The measurements of different parameters of the right and left clavicles were as follows.

Length of the clavicle: (Graph 1)

In males: The mean length of the right clavicle was 160.121.9± mm and that of the left clavicle was 162.515.5± mm.

In females: The mean length of the right clavicle was 155.619.7± mm and that of the left clavicle was 160.319.6± mm.

Medial angle of clavicle: (Graph 2)

In males: The mean medial angle of the right clavicle was 160.2 ± 5.9° and the mean medial angle of the left clavicle was 160.4 degrees ± 8°

In females: The mean medial angle of the right clavicle was 156.3 ± 5.2° and the mean medial angle of the left clavicle was 157.2 ± 5.2°.

Lateral angle of the clavicle: (Graph 3)

In males: The mean of the lateral angle of the right clavicle was 147.3 ± 8.3° and the mean of the lateral angle of the left clavicle was 152.7 ± 8°

In females: The mean of the lateral angle of the right clavicle was 148.1 ± 12.7° and the mean of the lateral angle of the left clavicle was 154.6 ± 9.5°

Height of medullary canal at the medial end of the clavicle: (Graph 4)

In males: The mean of the height of medullary canal in the right clavicle was 10.09 ± 2.8 mm and that of the left clavicle was 10.12 ± 2.7 mm.

In females: The mean of the height of medullary canal in the right clavicle was 7.2 ± 3.2 mm and that of the left clavicle was 7.5 ± 3.1 mm.

Width of medullary canal at the medial end of the clavicle: (Graph 5)

In males: The mean of the width of medullary canal at the medial end of the right clavicle was 10.6 ± 2.5 mm and that of the left clavicle was 10.9 ± 2.1 mm.

In females: The mean of the width of medullary canal at the medial end of the right clavicle was 7.8 ± 2.6 mm and that of the left clavicle was 7.6 ± 2.2 mm.

Height of the medullary canal at the middle part of the clavicle: (Graph 6)

In male: The mean of the height of the medullary canal at the middle part of the right clavicle was 6.4 ± 2.2 mm and that of the left clavicle was 6.6 ± 2 mm.

In females: The mean of the height of the medullary canal at the middle part of the right clavicle was 4.7 ± 2.2 mm and that of the left clavicle was 4.8 ± 2.2 mm.

Width of the medullary canal at the middle part of the clavicle: (Graph 7)

In males: The mean of the width of the medullary canal at the middle part of the right clavicle was 6.6 ± 2.3 mm and that of the left clavicle was 6.6 ± 2.1 mm.

In females: The mean of the width of the medullary canal at the middle part of the right clavicle was 6.6 ± 2.3 mm and that of the left clavicle was 6.6 ± 2.1 mm.
Clavicle was 4.2 ± 0.9 mm and that of the left clavicle was 4.5 ± 1.4 mm.

**Height of the medullary canal at the lateral end of the clavicle:** (Graph 8)

**In males:** The mean of the height of the medullary canal at the lateral end of the right clavicle was 7.7 ± 2.1 mm and that of the left clavicle was 7.4 ± 2 mm.

**In females:** The mean of the height of the medullary canal at the lateral end of the right clavicle was 5.8 ± 2.5 mm and that of the left clavicle was 5.3 ± 2.2 mm.

Width of the medullary canal at the lateral end of the clavicle: (Graph 9)

**In males:** The mean of the width of the medullary canal at the lateral end of the right clavicle was 7.8 ± 2.3 mm and that of the left clavicle was 7.9 ± 2.8 mm.

**In females:** The mean of the width of the medullary canal at the lateral end of the right clavicle was 4.9 ± 2.6 mm and that of the left clavicle was 4.8 ± 2.2 mm.

**Start of the medullary canal at the sternal end of the clavicle:** (Graph 10)

**In males:** The mean length at which the canal start was 4.9 ± 0.8 mm from the sternal end in right clavicle and that of the left clavicle was 5.3 ± 1 mm from the sternal end.

**In females:** The mean length at which the canal start was 4.6 ± 1.5 mm from the sternal end in right clavicle and that of the left clavicle was 4.51.5 ± mm from the sternal end.

**End of the medullary canal at the acromial end of the clavicle:** (Graph 11)

**In males:** The mean of the length at which the medullary canal ends from the acromial end in right clavicle was 6.17 ± 1.5 mm and that of the left clavicle was 5.7 ± 1.2 mm.

**In females:** The mean of the length at which the medullary canal ends from the acromial end in right clavicle was 4.81.3 ± mm and that of the left clavicle was 5 ± 1.9 mm.

**Length of the medullary canal:** (Graph 12)

**In males:** The mean length of the medullary canal in right clavicle was 148.7 ± 21.4 mm and that of the left clavicle was 151.3 ± 15.6 mm.

**In females:** The mean length of the medullary canal in right clavicle was 146.2 ± 19 mm and that of the left clavicle was 150.7 ± 18.6 mm.

**Fig. 1:** A 3D computed tomography photo showing the measurement of the length of both clavicles using the point tracing method.

**Fig. 2:** A 3D computed tomography photo showing the measurements of the medial and lateral angles of both clavicles.

**Fig. 3:** A computed tomography photo (coronal section) showing how to measure the height of medullary canal of both clavicles.
Curvatures and medullary canal of the clavicles.

**Fig. 4:** A computed tomography photo (coronal section) showing how to measure the width of medullary canal of both clavicles.

**Graph 1:** Length of right and left clavicle in both genders

**Fig. 5:** A computed tomography photo (horizontal section) showing the measurements of the length at which the medullary canal begins.

**Graph 2:** Medial angle of right and left clavicle in both genders

**Fig. 6:** A computed tomography photo (horizontal section) showing the measurements of the length at which the medullary canal ends.

**Graph 3:** Lateral angle of right and left clavicle in both genders

**Graph 4:** Height of medullary canal of medial end of right and left clavicle in both genders

**Graph 5:** Width of medullary canal of medial end of right and left clavicle in both genders
DISCUSSION

The human clavicle has a highly variable and complex bony anatomy that makes accurate study of its morphology a challenge. Literatures have pointed out that morphology of the clavicle shows a number of intra and inter-individual variations (Andermahr et al., 2007). These anatomical variations can make the use of fixation devices for the treatment of clavicle fractures challenging (Huang et al., 2007).
Although the anatomy of the clavicle has been widely studied using cadaver and bone bank specimens, computed tomography imaging has been shown to be an accurate method for describing the anatomy of the clavicle (Sinha et al., 2011). The dimensions of the clavicle and its canal were determined in living subjects avoiding possible post-mortem changes (Galley et al., 2009).

The CT scans with coronal and sagittal reformating and 3D reconstruction were performed on one hundred clavicles belonging to fifty subjects. Measurements of different parameters of the clavicles were taken. Concerning the length of male clavicles was found to be generally longer than female clavicles. Again the length of the left clavicle was longer than that of the right clavicle in both sexes. This side difference might be attributed to hand dominance and different workloads of the respective upper limbs during growth (Chavada et al., 2013).

The other important point concerning the length of the clavicle observed in the current study was that the length of Egyptian clavicles were longer than those of the French clavicles (Olivier, 1951), Northwest Indians (Kaur et al., 2002) and South Indians (Sudha, 2014). This could be explained by racial or genetic factors. (Chavada et al., 2013) claimed that the variations in the length of the clavicle may be also related to the nutritional factors.

In the present study, the medial as well as the lateral angle of the left clavicle were greater than that of the right clavicle in both sexes, indicating that the curves of the right clavicle are greater than that of left clavicle which led to a shorter right clavicle as compared to the left one. Similar findings were reported by (Haque et al., 2011).

In the current work, the height and width of the medullary canal of the clavicle were generally greater in males than in females who have a relatively smaller canals. Again the height and width of the medial and lateral ends of the medullary canal were greater than the height and width of its mid-region. Hence the mid-region of the medullary canal is the narrowest part and the cross sectional area then gradually increase towards both the acromial and sternal ends.

The three dimensional anatomical studies can provide more information than the traditional two dimensional studies (Daruwalla et al., 2010). These information have a great importance when considering intramedullary nailing techniques (Bachoura et al., 2013), where common intraoperative and postoperative complications could be avoided by proper examination of the anatomy of the clavicle (Andermahr et al., 2007).

CONCLUSION

Computed tomography imaging has shown to be an accurate method for describing the anatomy of the clavicle. Data could be used to determine whether the anatomy of the clavicle and its medullary canal are suitable for intramedullary fixation.

REFERENCES


تقوسات عظام الترقوه وتجويفها النخاعي في المصريين: دراسة ثلاثية الأبعاد باستخدام الأشعة المقطعية

تتناول عظام الترقوه من أكثر العظام تعرضا للكسر في الهيكل العظمي. الكسور التي ت تعالج بأسلوب غير جراحي تحمل احتمال أعلى لعدم الالتأم أو الالتأم الخاطئ. التعامل الجراحي مع الكسر يعني نتائج أعلى من التعامل غير الجراحي و يكون بالثبيت الخارجي أو الثنيات الداخلي. الثنيات الخارجي غير مريح وله أثر تجميلي غير مرغوب فيها. أما الثنيات الداخلي للكسر فله نتائج أفضل و مضاعفات أقل و لكن شكل و حجم التجويف النخاعي يعتبر عامل هام في نجاح تركيب مسمار الثنيات الداخلي.

الهدف من البحث: تم تصميم هذا البحث لدراسة تقوسات عظام الترقوه وتجويفها النخاعي من أجل دراسة الميزات المورفولوجية للترقوه بين المصريين وتحقيق ما إذا كانت الترقوه وتجويفها النخاعي قابلة للتسمير النخاعي في حالات كسر العظام لا.

الطريقة والمواد المستخدمة: تم الدراسة على مائة ترقوه باستخدام الأشعة المقطعية ثلاثية الأبعاد مع عمل منقشات تاجية وطولية لمرضى لا يعانون من مدخلي طبيعي في عظام الترقوه.

النتائج: فيما يتعلق بطول عظام الترقوه لوحظ أن الترقوه عند الذكور أطول منها عند الإناث، و كانت الترقوه اليسرى أطول من اليمين في كلا الجنسين. أما عن الزاوية الأندية و الجانبية فقد كانا أكبر على الجانب الأيسر في الذكور والإناث. أما فيما يتعلق بإبعاد القناة النخاعية للترقوه فقد كانت الإبعاد عند الذكور أكبر منها عند الإناث.

الخلاصة: الأشعة المقطعية لها دور أساسي لتقدير إعداد وتقويم ترقوه عظام الترقوه وتجويفها النخاعي لبيان إمكانية تركيب مسمار نخاعي للثنيات الداخلي لكسور عظام الترقوه.

مفاتيح الكلمات: تقوسات عظام الترقوه - تجويف نخاعي الأشعة - المقطعية.