Current concepts in clavicle fractures

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Abstract

Clavicle fractures are common injuries which any orthopaedic surgeon encounters in the clinical practice. There are ongoing debates about the optimal treatment for displaced fractures and a consensus is yet to be agreed. This article aims to present an overview on current concepts and suggest some recommendations for the management of these injuries.

Keywords clavicle fixation; clavicle fractures; distal clavicle; medial clavicle; middle clavicle; midshaft clavicle

Introduction

Clavicle fractures account for approximately 2–4% of all fractures, with an increase in incidence due to a higher involvement of population in contact sports and development of faster vehicles. Mechanism of injury for young adults is usually sports related (direct fall onto the shoulder or on an outstretched hand) or due to high-energy road traffic accidents. In the elderly population, these fractures are sustained by a simple fall from a standing height. In children, clavicle fractures can be sustained at birth through a forceful delivery or during childhood by a direct fall on the point of the shoulder. Non-accidental injuries should also be suspected in high-risk patients (vulnerable adults and children).

Development, anatomy and function

Development

Clavicle is the first bone to ossify, a process which starts in the fifth to sixth week of intrauterine life and is the only long bone of the body to form by intramembranous ossification. There are two primary ossification centres, which fuse approximately one-third to one-quarter from the lateral end. A secondary centre appears in the medial end and begins to ossify between 12 and 19 years of age. The ossification process and fusion of the secondary centre completes at the age of 22–25. This fact must be remembered as an epiphyseal fracture can be mistaken for a sterno-clavicular joint dislocation in a young adult in whom fusion of the medial ossification has not completed. The lateral clavicle forms by intramembranous ossification whilst the medial end is formed by enchondral ossification, with the medial clavicle contributing more substantially to the growth in length.

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Anatomy

The clavicle is an S-shaped bone, being convex medially and concave laterally and connects the axial skeleton with the appendicular skeleton. It is located subcutaneously and is easily accessible for inspection and palpation throughout its entire length, between the medial and lateral ends. The overlying skin is very elastic, allowing easy retraction during surgical exposure of the clavicle. It articulates with the manubrium sternum at the medial end, which is situated slightly superior than the sternum. At the lateral end the clavicle is connected to the scapula by direct articulation with the acromion and through the coracoclavicular ligament. The sternoclavicular and acromioclavicular joints contain fibrocartilage and an intra-articular disc.

The acromioclavicular joint is stabilized by the superior, inferior, anterior and posterior acromioclavicular ligaments (most important ones being the superior and posterior) and coracoclavicular ligament, with the conoid and trapezoid components (Figure 1). Conoid ligament inserts approximately 4.5 cm medial to acromioclavicular joint on a bony prominence situated on the postero-inferior aspect of the clavicle (conoid tubercle) and prevents supero-inferior displacement. Trapezoid ligament attaches on the inferior surface of the clavicle and its main role is to limit antero-posterior translation. The coracoid attachment of the coracoclavicular ligament is located at the most posterior and dorsal aspect of the coracoid angle.

The sternoclavicular joint stability is mainly achieved by an intact costoclavicular ligament (Figure 1) with the joint capsule and interclavicular ligament also playing an important role.

The clavicle can be divided into a medial two-thirds and a lateral third. The medial two-thirds has four surfaces:

- superior, providing the attachment for sternocleidomastoid muscle
- inferior, with the costal tuberosity for the attachment of costoclavicular ligament (medially) and subclavian groove (laterally) where subclavian muscle inserts
- posterior, providing the attachment of sternohyoid muscle
- anterior, which is convex and has the insertion of pectoralis major.

The medial part of the clavicle is covered by platysma and deep to this structure the supraclavicular nerves are localized. These nerves are often sacrificed during operative fixation of clavicle fracture resulting in a patch of numbness in the infraclavicular region.

The lateral third has two surfaces and two borders:

- superior surface, subcutaneous
- inferior surface, with the coracoclavicular ligament attachment
- anterior border, providing the attachment for deltoid muscle
- posterior border, with the insertion of trapezius muscle.

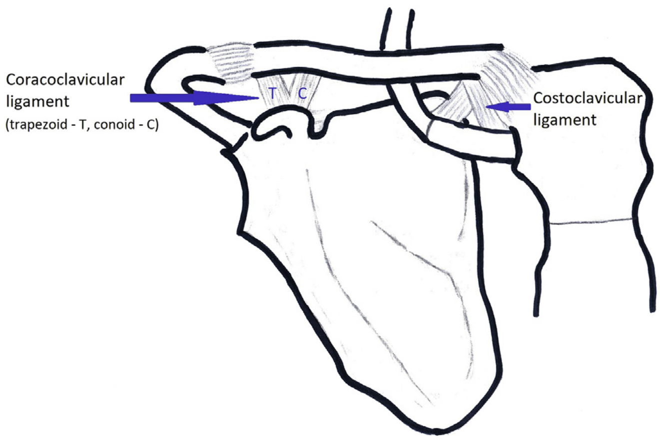

Figure 1 Coracoclavicular and sternoclavicular ligaments.

For midshaft and medial clavicle fractures, the surgeon must be aware of the relation of the bony fragments to the neurovascular structures (brachial plexus, subclavian artery and vein) and apex of the lung which may be injured during operative fixation. A radiological study by Sinha et al.[1] demonstrated that the subclavian artery and vein are situated postero-inferiorly at 17.02 mm and 12.45 mm from the middle clavicle and at a mean angle of 50° and 70° respectively, to the horizontal. Furthermore, the subclavian artery and vein are very closely related to the medial end of the clavicle, with the vein being localized immediately behind the posterior cortex in some cases.

Function

The clavicle has several important functions, as follows.

1. It increases the power and stability of the arm by providing attachment to important muscles (deltoid, trapezius, sternocleidomastoid, pectoralis major, subclavius) and ligaments (coracoclavicular, costoclavicular).
2. It has a role in arm mobility, mainly above the level of the shoulder.
3. It protects the subclavian vessels, brachial plexus and apex of the lung.
4. Its cosmetic role becomes evident with malunited clavicle fractures or chronically dislocated acromioclavicular joints, especially in female patients.

Classification

Several classifications of clavicle fractures have been designed. In 1967, Allman classified clavicle fractures in thirds, depending on localization of the fracture line: Group I — middle third (most common), Group II — lateral third, distal to coracoclavicular ligaments (non-union common) and Group III — proximal end.

Robinson classified these injuries according to degree of displacement, articular involvement and comminution (Table 1) and proposed predictive models to calculate the risk of non-union. The author suggested that diaphyseal fractures have a higher risk of non-union with advanced age, female gender, higher degree of displacement and comminution whereas for lateral end fractures this risk is increased when displaced, especially in elderly population.

Neer further subclassified lateral end clavicle fractures depending on position of fracture line in relation to coracoclavicular ligament, providing information on the stability of these injuries (Table 2, Figures 2—6). He also grouped middle third fractures in less than 100% displaced (suitable for non-operative management) and more than 100% displaced with a 4.5% risk of non-union, in which operative management needs to be considered.

In 1990, Craig proposed a classification based on position of fracture line, grade of comminution and added the paediatric component which is not present in any of the other systems presented above (Table 3).

If we also consider the AO classification of middle third fractures depending on fracture pattern and complexity (Table 4), we realise that we are faced with a multitude of classification systems which need to reflect in the decision process of definitive management of these injuries. A comparison study on existing classification systems of clavicle fractures[2] suggested that Robinson's classification demonstrated the best prognostic value for delayed or non-union for middle third fractures, whereas Craig's classification was the preferred one for lateral third fractures.

Examination and investigations

Clinical examination

Examination of clavicle fractures is straightforward, with no special tests to be performed. In cases of polytrauma, the patient should be systematically approached using the Advanced Trauma Life Support principles. Once any life-threatening injuries have been ruled out or addressed, clavicle examination will be performed as part of the secondary survey. Inspection should comment on presence of local swelling, bruising, deformity, shoulder asymmetry/shortening. Documenting the skin condition (tented, lacerated, discoloured) is an important part of

Robinson classification of clavicle fractures

Type 1 Medial one-fifth fracture	Type 2 Middle three-fifths fracture	Type 3 Lateral one-fifth fracture
a. Undisplaced	a. Cortical alignment fractures	a. Undisplaced
1. Extra-articular	1. Undisplaced	1. Extra-articular
2. Intra-articular	2. Angulated	2. Intra-articular
b. Displaced	b. Displaced fractures	b. Displaced
1. Extra-articular	1. Simple wedge comminution	1. Extra-articular
2. Intra-articular	2. Multifragmentary, segmental	2. Intra-articular

Table 1

Neer classification of clavicle fractures

Type 1	Type 2	Type 3
Middle third (80%)	**Distal end (15%)** **Subtypes:** I Lateral to coracoclavicular (CC) ligaments (stable) — Figure 2 II a. Medial to CC ligaments (unstable) — Figure 3 II b. Fracture between CC ligaments (torn conoid, trapezoid intact) or lateral to CC ligament (torn conoid and trapezoid) — Figures 4 and 5 III Intra-articular (extending into acromioclavicular joint), intact CC ligament — Figure 6	**Medial third (5%)**

Table 2

Figure 2 Neer Type I distal end clavicle fracture. Stable injury.

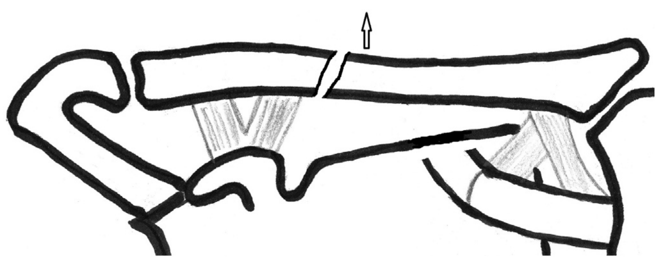

Figure 3 Neer Type IIa distal end clavicle fracture. Medial clavicle displaces upwards.

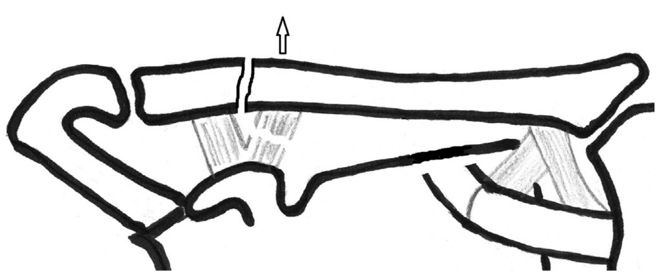

Figure 4 Neer Type IIb distal end clavicle fracture (between coraco-clavicular ligament). Medial clavicle displaces upwards.

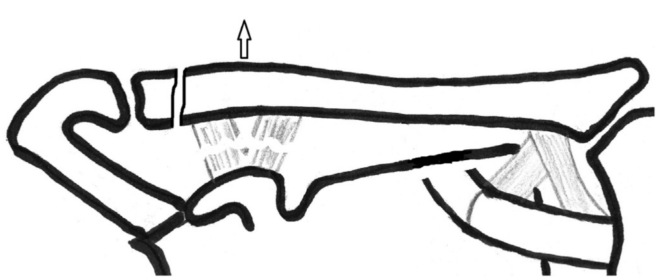

Figure 5 Neer Type IIb distal end clavicle fracture (lateral to a torn coracoclavicular ligament). Medial clavicle displaces upwards.

Figure 6 Neer Type III distal end clavicle fracture. Stable injury.

inspection as this will determine whether surgical fixation becomes an absolute rather than relative indication. Palpation will demonstrate local tenderness or bony crepitus. Range of movements of the corresponding shoulder will be reduced and painful and the patient should be asked to perform these within reasonable limits in acute situation. Clinical examination is completed with neurological and vascular assessment of the affected limb which needs to be clearly documented in patients' notes.

It is also important to be mindful of other concomitant injuries that can be associated with high-energy clavicle fractures. This includes examining the scapula, ribs (and associated lung injury), cervical spine and sternum.

Imaging

Clavicle fractures are initially investigated with a set of two X-rays: antero-posterior view and 15° cephalic tilt (ZANCA view), the latter being useful in evaluating supero-inferior displacement. The spine of scapula can occasionally interfere with clear visualization of clavicle fracture morphology and the 15° cephalic tilt view can be helpful in these circumstances. In suspected established non-union, a CT scan could provide valuable information.

Treatment

As for any other fracture, non-operative and operative treatments also apply to clavicle fractures. Absolute indications for surgical intervention are:

1. Open fractures
2. Floating shoulder
3. Displaced fracture which threatens skin viability
4. Subclavian artery or vein injury
5. Symptomatic non-union

Any other indications (displaced fracture, bilateral fractures, shortening >2 cm in midshaft fractures, brachial plexus injury,

Craig classification of clavicle fractures

Craig's classification		
Type 1 Middle one-third	**Type 2 Distal one-third**	**Type 3 Proximal one-third**
	a. Minimally displaced b. Displaced fractures, fracture medial to coracoclavicular (CC) ligament 1. Conoid and trapezoid intact 2. Conoid torn, trapezoid intact c. Fractures into articular surface d. Fractures in children, intact CC ligaments attached to periosteal sleeve, proximal fragment displaced e. Comminuted fractures	a. Minimally displaced b. Displaced c. Intra-articular d. Epiphyseal separation e. Comminuted

Table 3

AO classification of clavicle fractures

Lateral clavicle	Diaphyseal clavicle	Medial clavicle
Undisplaced (CC intact) • Extraarticular • Articular	Simple • Spiral • Oblique • Transverse	Extra-articular
Displaced (CC intact) • Extra-articular • Fragmentary	Wedge • Intact spiral wedge • Intact bending wedge • Fragmentary wedge	Articular
Displaced (CC disrupted) • Extra-articular • Articular	Multifragmentary • Fragmentary spiral • Intact segmental • Fragmentary segmental	Complete articular

CC, coracoclavicular.

Table 4

closed head injury, polytrauma patient, unstable fracture pattern IIa or IIb in distal clavicle fractures, pathological fractures) are open to debate and remain relative indications.

Midshaft fractures

Non-displaced middle third clavicle fractures are treated with a sling for comfort purposes and early mobilization depending on pain level.

Management of displaced midshaft clavicle fractures remains controversial despite the large number of studies being published on this topic with researchers continuing to investigate the best treatment option.

The release of the Canadian Orthopaedic Trauma Society Study in 2007[3] constituted a turning point towards operative fixation of these injuries. The authors suggested that overall patients' satisfaction was higher in the surgically treated group, with a better Constant and DASH score at all time points ($p = 0.001$ and $p < 0.01$, respectively) and a better non-union rate than those treated non-operatively (2 out of 62 vs 7 out of 49, $p = 0.042$). However, 14% of those in the operative group had problems related to metalwork (five cases – prominent metalwork, three cases – infection, one case – mechanical failure). Leroux et al.[4] reported a 24.6% reoperation rate following plate fixation, the main reason being isolated implant removal (18.8%). Other complications include infection (2.6%), non-union (2.6%), malunion (1.1%), pneumothorax (1.2%), injury to brachial plexus and subclavian vessels.

In 2013, Robinson et al.[5] published a multicenter, randomized, controlled trial on plate fixation versus nonoperative treatment for displaced clavicle fractures which was conducted on 200 adult patients. The authors suggested that risk of non-union was significantly decreased by surgical intervention ($p = 0.007$) and overall, functional outcome at 12 months were significantly better for the operative group. However, when patients with non-union were excluded from the analysis, Constant and DASH scores were not statistically significantly different between operative and non-operative groups at any time point. There was also a significantly higher cost associated with operative treatment ($p < 0.0001$). The conclusion was that the study did not support routine primary open reduction and plate fixation for midshaft clavicle fractures.

An expectative approach is also suggested by Das et al.[6] in their study on early versus delayed surgical fixation for symptomatic fractures. There was no statistically significant difference in terms of patients' reported outcome measures (Oxford Shoulder Scores, EQ5D, QuickDASH) between the two groups. Thus, the authors recommend delayed fixation for symptomatic clavicle fractures.

In 2017, Ahrens et al.[7] published a multicentre, randomized controlled trial, comparing operative versus non-operative management of displaced midshaft clavicle fractures. The study was conducted on 301 eligible patients and assessed rate of non-union at 3 months and 9 months, limb function and patient satisfaction. They concluded that surgical treatment offers superior functional outcomes and a significantly lower non-union rate (<1%) than non-operative management (11%), results which are in keeping with Robinson's study[5] before the symptomatic non-unions were excluded from the analysis.

A meta-analysis of randomized controlled trials published by Woltz et al.[8] suggested that operative fixation reduces the risk of non-union, but does not offer a significantly better clinical outcome than non-operative treatment. Although risk of non-union was lower in surgical group, one-third of patients with non-union did not receive further treatment. The authors concluded that there is not enough evidence to support routine operative treatment for all patients with displaced midshaft clavicle fractures.

When open reduction internal fixation is indicated, various techniques are available: pre-contoured plates with a combination of locking/non-locking screw options (superior or antero-inferior plates), intramedullary elastic nailing, external fixation. A meta-analysis by Nourian et al.[9] demonstrated similar results between antero-inferior versus superior plates in terms of Constant score, union rate, infection rate and implant failure, but superior plates have a higher rate of symptomatic hardware ($p = 0.005$) and implant removal ($p = 0.008$). Fuglesang et al.[10] suggested that if open reduction is required, plate fixation should be preferred to elastic intramedullary nailing due to faster functional recovery and a lower rate of implant removal.

A few important conclusions can be made after reviewing the literature, as follows.

1. Risk of non-union is higher when these fractures are treated non-operatively (11–14% versus 0.8–3%), but not all non-unions will require further treatment.
2. When excluding the non-unions, operative treatment does not seem to offer a significantly better outcome than non-operative management.
3. A delayed operative approach to symptomatic clavicle fractures is acceptable.
4. Risk of re-operation is relatively high in surgically treated patients with potential devastating injuries (pneumothorax, injury to brachial plexus, subclavian vessels).
5. Plating is preferred to intramedullary nailing.
6. There is a higher cost associated with operative fixation.

We recommend that patients take part in the decision-making process and should be thoroughly explained the pros and cons of each of the possible treatments.

Distal end clavicle fractures

Neer Type I and III closed fractures are stable and suitable for non-operative management in a sling for 2–4 weeks with gentle range of movements as pain allows. Craig Type 2d injury (clavicle pulls out of periosteum) is a stable injury with intact coracoclavicular ligaments and can be treated non-operatively.

Controversy arises for unstable fracture patterns (Neer type IIa, IIb and Craig type 2e) where the stability conferred by the coracoclavicular ligaments is compromised. According to Robinson et al.,[11] the most important predictive factors for non-union are age (elderly population) and displacement. If treated non-operatively, these injuries result in a non-union rate of 33.3% but often with an acceptable functional outcome.[12] This method of treatment is usually reserved for elderly patients with significant associated co-morbidities who do not fulfil the criteria for absolute indication for surgical fixation.

Operative treatment comprises of different techniques: hook plating, distal clavicle locking plate, coracoclavicular stabilization, transacromial pinning, tension band wiring. A systematic review by Boonard et al.[13] demonstrated significantly better Constant scores when using coracoclavicular fixation as compared to hook plate and tension band wiring, with pooled mean of 2.98 (95% CI 0.05–5.91) and 7.11 (95% CI 3.04–11.18). Plate and screw fixation presented lower risks when compared to coracoclavicular fixation, hook plating, tension band wiring and transacromial pinning. Therefore, the authors recommend plate and screw and coracoclavicular fixation as the first and second line treatment of unstable distal clavicle fractures. These two fixation modalities can often be combined to get the best structural construct. Satisfactory functional outcome in terms of Constant score and DASH score, low complication rate and 100% union rate were reported by Han et al.[14] on surgical fixation of Neer IIb with anatomical locking plate fixation combined with coracoclavicular ligament augmentation. Indirect osteosynthesis is achieved by coracoclavicular ligament reconstruction alone[15] with very good reported functional outcomes and significantly lower complication rate than hook plating (0% vs 24.5%, $p = 0.007$).[16]

Hook plate was and in some places is still being used as the preferred fixation implant for displaced distal clavicle fractures. However, this device carries the disadvantage that it requires removal at a later stage (usually between 3 and 6 months) in order to prevent acromial or humeral head erosion and injury to the rotator cuff. Zhang et al.[17] demonstrated that complication rate related to hook plate fixation rises significantly from 10% when removed earlier than 3 months to 22.9% when removed between 3 and 6 months and up to 50% if removal is later than 6 months. Constant score was significantly better in the early removal group (<3 months) as compared to delayed removal (3–6 months) and late removal groups (>6 months): 96 versus 77 versus 61. A complication rate of 40.7% was also reported by Oh et al.[12] in their systematic review on 425 distal end clavicle fractures, using the hook plate. In a comparison study between hook plating and tension band wiring of unstable distal clavicle fractures, Wu et al.[18] demonstrated a 13% complication rate following hook plating (periprosthetic fractures, plate removal, plate malposition) and 29% with tension band wiring (wire migration, loss of reduction, wire breakage), both groups requiring a second operation to remove the metalware. Therefore, newer implants like distal clavicle locking plates have been designed to eliminate the need for routine implant removal and the results indicate that these have a lower complication rate ($p < 0.05$) and symptomatic hardware ($p < 0.05$) than hook plates.[19] Patients who underwent open reduction internal fixation with distal clavicle plates also had a better return to work than those treated with hook plating.[19] Distal clavicle locking plates can be used with or without coracoclavicular ligament augmentation techniques with very good reported functional outcomes (Constant score, DASH, UCLA) and excellent union rate (100%).[14,20] More recently, arthroscopically assisted fixation techniques have been developed[21] (single or double endobutton/dogbone) with similar results to open procedures.[22]

Based on existing published literature and acknowledging that strong quality studies are still needed, we can conclude that for unstable distal clavicle fractures (Neer type IIa, IIb and Craig type 2e):

1. Risk of non-union is high, but functional outcomes are overall acceptable with non-operative treatment and these should be discussed in detail with the patient who needs to be engaged in the decision making process

2. Hook plates have a high complication rate and require second intervention for plate removal; timing of second procedure is very important to reduce complications.
3. When surgery is indicated and agreed with the patient, direct fixation with distal clavicle plates with or without coracoclavicular ligament augmentation or indirect fixation with coracoclavicular ligament reconstruction alone have a low complication rate, good functional outcomes and achieve excellent union.

Medial end

Although medial end clavicle fractures are uncommon, they are associated with high-energy chest injuries with a reported mortality rate between 4.4% and 20%.[23,24] Some of these injuries are missed on simple radiographs but they are always identified on CT trauma series.[23]

Salipas et al.[24] reported a series of 68 patients with medial end clavicle fractures, mostly sustained through a high energy mechanism (motor vehicle accidents) with an equal distribution between intra and extra-articular fractures. The authors suggested that only 2 patients (2.9%) required operative treatment for painful non-union, both having presented with severe fracture displacement on initial assessment. Overall, non-operative management of medial clavicle fractures provided an excellent functional result. Despite the high energy mechanism, patients report little or no pain from these injuries on final follow-up.[23]

Based on the above findings, we recommend a non-operative management of medial end clavicle fractures in the absence of absolute indications for operative treatment which have been listed above.

Conclusion

Clavicle fractures are common injuries encountered in orthopaedic practice. There are various treatment options for these fractures, but we recommend that patients should be actively involved in the decision-making process. ◆

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