Midshaft Clavicle Fractures: A Critical Review

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abstract

The clavicle is the most commonly broken bone in the human body, accounting for up to 5% to 10% of all fractures seen in hospital emergency admissions. Fractures of the middle third, or midshaft, are the most common, accounting for up to 80% of all clavicle fractures. Traditional treatment of midshaft clavicle fractures is usually nonoperative management, using a sling or figure-of-eight bandage. The majority of adults treated nonoperatively for midshaft clavicle fractures will heal completely. However, newer studies have shown that malunion, pain, and deformity rates may be higher than previously reported with traditional management. Recent evidence demonstrates that operative treatment of midshaft clavicle fractures can result in better functional results and patient satisfaction than nonoperative treatment in patients meeting certain criteria. This article provides a review of relevant anatomy, classification systems, and injury mechanisms for midshaft clavicle fractures, as well as a comparison of various treatment options. [*Orthopedics*. 2016; 39(5):exxx-exxx.]

The clavicle is the most commonly broken bone in the human body, accounting for up to 5% to 10% of all fractures seen in hospital emergency admissions. These injuries are most common in younger patients, often associated with direct trauma to the clavicle, as in contact sports and motor vehicle accidents. Males are affected more than females, and prevalence declines progressively with age, although traumatic falls in elderly patients cause a bimodal peak in age distribution.[1] The clavicle is classically divided into thirds when describing the location of the fracture. Fractures of the middle third, or midshaft, are the most common, accounting for up to 80% of all clavicle fractures.[2,3] The location of the fracture, along with degree of displacement and association of surrounding structures, is important to consider for treatment. Traditionally, clavicle fractures have been treated with nonoperative management, but high-quality randomized studies have recently begun to change the evidence-based management of these fractures.[4] The current review will present some relevant findings in the ongoing debate.

Anatomy

The clavicle is a long, dual-curved bone that forms the only direct link between the axial and appendicular skeletons.[5-7] It is the first bone in the body to be ossified[7,8] (begins at 5 to 6 weeks' gestation)[9] and the last bone to complete ossification[8] (the medial epiphysis completes ossification as late as age 27 years).[10] It is a highly variable structure in terms of length, although many studies have shown the length to be approximately 140 to 150 mm (range, 118-162 mm).[11-13]

Fractures of the clavicle are common for many reasons, including its location in

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the human body, its structure, and its articulations. Its location is superficial, just beneath the skin and thin platysma muscle, making it one of the least-protected bones by muscle or fat.[14-16] The clavicle is also a relatively thin bone. According to a study by Andermahr et al,[17] mean cortical thickness was only 2.05 mm at the midpoint of the clavicle. Combined with the fact that the clavicle is slightly curved at the middle third, the midshaft is especially weak and susceptible to fracture.[13,16]

The clavicle has 2 main articulations, forming the sternoclavicular joint with the manubrium sternum medially and the acromioclavicular joint with the acromion of the scapula laterally.[5,7,14] Although all joints are susceptible to damage, these joints provide substantial muscular and ligamentous support, both of which are absent in the middle third of the clavicle, making it an area of susceptibility to fractures.[16]

Surrounding Structures and Risks

Around the midshaft area of the clavicle, there are several important structures that can be affected when a fracture occurs. Important muscles that surround or attach to the clavicle include the deltoid, trapezius, subclavius, pectoralis major, and sternocleidomastoid with the coracoclavicular (trapezoid and conoid) ligaments.[14-16] Although the vast majority of clavicle fractures are uncomplicated and nondisplaced, the muscular attachments can displace the fracture fragments. Often, the sternocleidomastoid pulls the medial fragments cranially[7,15,18] and posteriorly,[7] whereas the lateral fragments are pulled inferiorly and rotated anteriorly by the weight of the shoulder.[7,18,19] The pull of the trapezius, pectoralis, and latissimus on the shoulder also medially shortens the fractured clavicle.[7,14,18] It is also possible for the displaced bone to button-hole through the platysma muscle.[15] The coracoclavicular, costoclavicular, and sternoclavicular ligaments are strong, and the joints at either end of the clavicle rarely dislocate.[5,20]

Surrounding neurovasculature includes the subclavian artery and vein, internal jugular vein, axillary artery, supraclavicular nerves, and brachial plexus.[14-16,19] These structures are sometimes damaged in association with the fracture, and they must also be considered when considering surgical intervention. The cupula of the lung lies just posterior to the clavicle, and pneumothorax is another potentially dangerous, although rare, complication.[21] These critical structures should be avoided or, when necessary, defined and made safe, especially when placing incisions and surgical implants in or on the clavicle.[7,14,16,17,22]

Epidemiology

Incidence of clavicle fractures ranges worldwide from 24 fractures per 100,000 population per year to 71 per 100,000, and it has been increasing over recent years.[23,24] These injuries occur more commonly in children and young adults, with most occurring in men younger than 25 years.[23] However, an increased incidence is also seen in older patients, commonly occurring in men and women aged older than 80 years.[15] Men are nearly 3 times more likely to sustain a clavicle fracture than women. The most common causes of clavicle fractures are motor vehicle accidents and sports injuries.

Classification of Clavicle Fractures

Since the 1960s, there have been a number of clavicle fracture classifications: Allman classification[25]; Neer classification[26]; Edinburgh classification, which was updated as Robinson classification[23]; Craig classification[26]; and OTA/AO classification.[27] Of these, the most widely used and accepted is the Allman classification. However, use of the Allman classification with Neer modification or the Robinson classification are increasing in popularity.[27] **Table 1** describes the differences between the classifications, and the **Figure** provides a visual comparison.

With this in mind, the need for a classification system based on clinical usefulness with respect to outcomes has been reported.[28] Alternative methods of classification based on morphology and divisions along the apices of curvature may provide more value with respect to indication for operative fixation.[13]

Mechanisms of Injury

The most common cause of clavicle fracture is direct or indirect trauma to the clavicle,[5,15,16] seen most often when falling directly onto the shoulder with the arm by the side. Sports injuries are responsible for up to 45% of clavicle fractures,[6,23] and they are especially common in direct contact sports such as American football (12% of midshaft clavicle fractures in the United States),[6] rugby,[23] and soccer (5.6% in the United States).[6,23] It is also commonly seen in cycling accidents (16% in the United States)[6,23,29] and less commonly in other nonsports injuries such as car accidents[6,23] and horse riding falls.[6] Another commonly described traumatic cause of midshaft clavicle fracture is falling onto an outstretched hand (FOOSH injury),[16,30] although it is difficult to generate adequate forces to cause fracture with this type of mechanism.[16,31] A midshaft clavicle fracture resulting from a ground-level fall onto an outstretched arm may indicate pathologic fracture in a young patient without osteoporotic bone.[18]

There are other causes of midshaft clavicle fractures, although these are much less common. These can be split into congenital causes, pathologic causes, and miscellaneous causes. Congenital causes of clavicle fractures are rare. The most important congenital cause is osteogenesis imperfecta, which is a disorder characterized by defective formation of collagen and hence the osteoid matrix.[32] Other congenital disorders that may increase the chances of clavicle fractures include oxalosis, which is a rare inborn

Table 1

Classification of Clavicle Fractures

Group/ Type	Allman Classification	Neer Classification	Robinson Classification	Craig Classification
1	Group I: Middle third fracture	Type I: Middle third clavicle fracture	Type 1: Medial fifth clavicle fractures: Nondisplaced Extra-articular Intra-articular Displaced Extra-articular Intra-articular	Type I: Middle third fractures
2	Group II: Fracture distal to CCL, nonunion common	Type II: Lateral third fracture; split into 3 subtypes: Type I, fracture medial to CCL Type II, fracture occurs at level of CCL-trapezoid remaining intact with distal segment Type III, fracture lateral to CCL entering the ACJ	Type 2: Middle 3/5th clavicle fractures: Type 2A: Cortically aligned fractures Nondisplaced Angulated Type 2B: Displaced fractures Simple wedge type Mutlifragmentary, segmental	Type II: Distal third fractures: Minimally displaced Displaced fractures, fracture medial to the CCL and trapezoid intact Conoid torn, trapezoid intact Articular surface fracture Fractures in children Intact CCL attached to periosteal sleeve, proximal fragment displaced Comminuted fractures
3	Group III: Proximal end clavicle fractures	Type III: Medial third fractures	Type 3: Lateral fifth clavicle fractures: Nondisplaced Extra-articular Intra-articular Displaced Extra-articular Intra-articular	Type III: Proximal third fractures: Minimally displaced Displaced Intra-articular Epiphyseal separation Comminuted

Abbreviations: ACJ, acromioclavicular joint; CCL, coracoclavicular ligament.

error of metabolism characterized by an excessive amounts of oxalate salts in the body. However, oxalosis affects mainly the medial third of the clavicle, and the middle third is rarely affected.[33]

Cancerous causes of pathologic fractures are also uncommon. In a study by Smith et al,[34] more than 30 malignant neoplasms were seen to cause pathological fractures, of which plasmacytomas, osteosarcomas, and Ewing's sarcomas were the most common. Other studies[35-41] further elaborate on the various primary malignant carcinomas of the clavicle that predispose to fractures. Other cancerous causes of pathologic fractures of the clavicle have been noticed in multiple myeloma,[42,43] which presents as lytic lesions that develop into fractures upon slight trauma or force. More rare cancers, such as malignant Langerhans cell histiocytosis,[44,45] have also been observed to cause clavicle fractures.

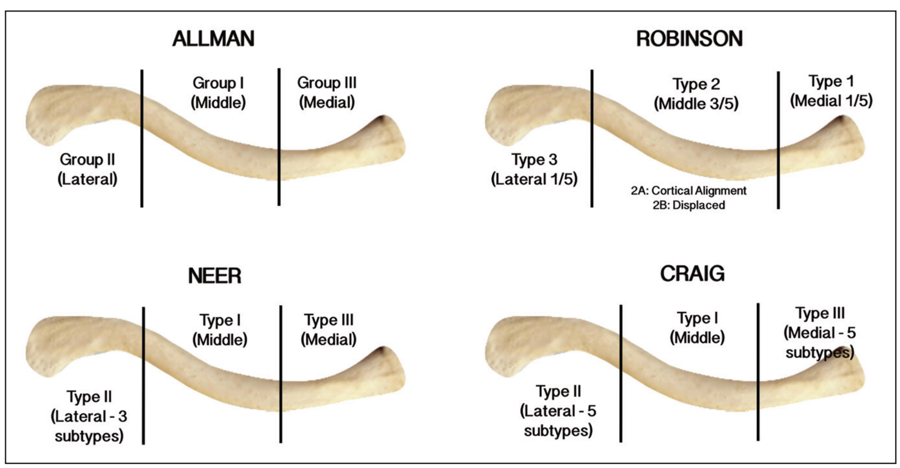

Figure: Visual comparison of the Allman, Neer, Robinson, and Craig clavicle fracture classification systems. Further information regarding classification of subtypes can be found in Table 1.

The clavicle is also an area for deposition of malignant metastases, and these have particularly been noticed in patients

Table 2

Indications for Operative and Nonoperative Management

Management	Indication	Relative Contraindication
Nonoperative	Nondisplaced fractures	Open fractures
	Skin intact	Multiple extremities injured
	Medically unfit for surgery	Skin tenting or impending skin necrosis
Operative	Comminuted fractures	Infection
	Fractures with 100% displacement fractures	Severe skin condition (eg, acne)
	Prolonged nonunion	Stroke patient with little extremity usage
	Open fractures	
	Floating shoulder	
	Neurovascular involvement	
	Significant shortening (>2 cm)	
	Vertical fragment	
	Infection	

with renal cell carcinoma, where up to 18% of patients will develop metastatic lesions in the clavicle.[46] Bony metastases from prostatic carcinoma and bronchogenic carcinoma have also been noted.[47]

An additional nonneoplastic cause of pathologic fractures is the effects of radiation therapy.[48] Radiation often causes diffuse demineralization of the bone with complete loss of trabeculae, increasing the risk of fractures. Less commonly, pathologic fractures of the clavicle have also been caused by abnormal arteriovenous malformations,[49] which often mimic neoplastic pathologic fractures and are only diagnosed during arteriography.

Miscellaneous causes of clavicle fractures are seen in obstetrics and occur as a complication of breech deliveries. Obstetricians can also deliberately induce clavicle fractures as a third-line management for shoulder dystocia (cleidotomy),[50] although this is now increasingly rare.[51]

Initial Assessment and Management

Initial assessment of clavicle fractures should include a thorough history and physical examination. Time and mechanism of injury, past medical history, hand dominance, occupational status, and smoking history should be obtained from the patient. Location of pain and presence of any paresthesias or subjective numbness should also be ascertained.

Physical examination should begin with visual assessment. The shoulder and clavicle should be carefully examined for asymmetry, ecchymosis, deformity, skin integrity, skin tenting, and swelling. The presence of lacerations or skin tenting should alert the examiner to the possibility of an open or impending open fracture. The clavicle should be palpated and assessed for crepitus, instability, and location of tenderness. A complete neurovascular examination should be completed distal to the injured clavicle, including palpation of distal radial and ulnar pulses; sensory examination of the radial, median, ulnar, and axillary nerve distributions; and a motor examination of the affected extremity. The patient should also be evaluated for associated injuries, including scapular fractures, rib fractures, acromioclavicular or sternoclavicular injury or dislocation, pneumothorax, brachial plexus injury, and flail limb.

Initial imaging should consist of plain radiographs of the clavicle and the ipsilateral shoulder. Radiographs of the contralateral shoulder or the chest can be obtained if there is concern for asymmetric acromioclavicular joint widening or injury. Oftentimes a computed tomography (CT) scan of the chest will have already been obtained in trauma patients, and the clavicle can be further assessed using data from the scan. Most modern imaging software can reconstruct a 3-dimensional image from the CT scan. However, a 20° downward-tilt anteroposterior radiograph has been shown to be equivalent to CT when assessing fracture shortening.[52]

Initial emergency room management of clavicle fractures should consist of immobilization in a sling[18,53] for comfort and pain control. Nonsteroidal anti-inflammatory drugs (NSAIDs) have been associated with higher rates of nonunion and infection in fractures,[54] and their use should be avoided in clavicle fractures. If the skin is tented or the fracture is open, urgent operative treatment is indicated.[18,55] Open fractures should also be treated with 24 to 72 hours of intravenous antibiotics and tetanus prophylaxis.[55,56]

Nonoperative Management

There are several methodologies and techniques for managing midshaft clavicle fractures. These managements can broadly be categorized into nonoperative and operative, indications for which can be found in **Table 2**. Generally, nonoperative treatment is more widely used in the initial management, with caveats to ensure skin and neurovascular safety. When assessing the literature with regard to the success of nonoperative management, the results and evidence-based recommendations have changed with time. This can be seen by performing retrospective analysis of studies performed by authors such as Neer[25] and Rowe.[57] They found that the nonoperative nonunion rate was low, with

Neer[25] reporting a rate of 0.13% in 2235 patients in 1960 and Rowe[57] reporting a rate of 0.8% in 566 patients in 1968.

However, a study by Hill et al[58] in 1997 showed that the nonunion rate was much higher at 15%. Hill et al[58] also showed that 30% of the patients with nonunions of their clavicle fractures reported poor functional results.[14] Furthermore, a 2012 meta-analysis found the nonunion rate to be 15% in nonoperatively treated midshaft clavicle fractures.[59] A more recent multicenter randomized, controlled trial (RCT) demonstrated a nonunion rate as high as 26% in those treated nonoperatively compared with 1% in those treated operatively (although there were no significant differences in return-to-work rates, and differences in functional outcomes were equivocal). In this study, smoking was shown to be an independent risk factor for nonunion.[60] Additional risk factors associated with nonunion include fracture displacement, fracture comminution, a vertically oriented butterfly fragment, female sex, and advanced age.[61,62] However, the literature continues to demonstrate that the majority of adults treated nonoperatively for midshaft clavicle fractures will go on to union.[60]

Initial nonoperative treatment involves immobilizing the involved shoulder with a sling or a figure-of-eight brace to maintain alignment during healing. The figure-of-eight brace has more recently fallen out of favor because it was found to cause patients discomfort and pain. Studies comparing a figure-of-eight brace to a regular sling have shown higher pain scores with the figure-of-eight brace but no difference in the rate of union or time until union between the 2 groups.[53,63] Some authors have also associated temporary brachial plexus palsies with figure-of-eight braces applied incorrectly.[18]

The sling is used for 4 weeks, after which active movements of the shoulder joint may be started. A light amount of work may also be commenced after 6 weeks, but no contact sports are recommended until at least 3 months after starting treatment.[14] The fracture is frequently monitored radiographically and through physical examination of the shoulder joint until satisfactory progress is made.

As previously discussed, nonoperative treatments of midshaft clavicle fractures can lead to functional deformities and nonunion. Shortening of the clavicle associated with nonunion can lead to pain with overhead movements, muscular dysfunction, and lack of strength.[14] Studies comparing bilateral clavicles in patients with a unilateral clavicle fracture concluded that an acceptable shortened length was 14 mm in females and 18 mm in males.[64] One study found that fractures with shortening of greater than 2 cm predispose to nonunion and recommended operative treatment for symptomatic patients with this condition. However, Nordqvist et al[65] concluded that acceptable results can be achieved by using nonoperative management for midshaft clavicle fractures. Out of a group of 225 patients managed nonoperatively, 185 reported good results and functional outcomes.[65]

Operative Management

There are 3 main options for surgical management of midshaft clavicle fracture: plate and screw fixation, intramedullary fixation, or external fixation. Each technique has certain advantages, indications, and disadvantages, often defined by patient and fracture characteristics.

Plate and Screw Fixation

Plate and screw fixation, also known as open reduction and internal fixation (ORIF), is considered the gold standard surgical option. Plate fixation has the benefit of being technically less demanding than intramedullary fixation.[66] For this operation, an incision is made similarly to intramedullary fixation to expose the fracture. Displaced pieces of clavicle are realigned with the use of clamps, sutures, and Kirschner wires to reestablish the normal anatomy of the clavicle and to secure the reduction. After this, a plate is placed on the surface of the clavicle, where it is aligned with the bone and secured with screw fixation. Construct design varies and is dependent on fracture pattern. Biomechanical studies show excellent clinical outcomes with precontoured plates compared with traditional plates,[67] as well as a decrease in postoperative hardware complications.[68] Plating provides rigid fixation, rotational control over the fracture, and the ability for cortical compression, but it can result in some damage to the surrounding neurovasculature and may require more stripping of the soft tissues.[14,53] Unicortical fixation has profiles in axial compression and axial load similar to bicortical fixation using precontoured plates and may provide a safer method of plating by reducing risk to surrounding structures.[69] Nonlocking plates are widely used and are biomechanically sound in cases where good bony apposition can be obtained, but locking plates provide stiffer constructs and are indicated in patients with osteoporotic bone or severely comminuted fractures.[70]

Plate positioning remains controversial. Traditional plate fixation consisted of superior placement, but anteroinferior plate placement has become more popular. Although superior plate placement allows fixation on the tension side of the fracture, it also results in prominent hardware with little soft tissue coverage and screw trajectories aimed toward neurovascular structures.[71] Theoretical benefits of anteroinferior plate placement include greater screw length and purchase, safer screw trajectory,[71] less prominent hardware, and less need for future hardware removal.[70,72] A comparison of the 2 plating techniques has shown that superiorly placed plates were removed more often due to symptomatic hardware than anteroinferiorly placed plates.[73] Biomechanical comparisons of the plate positions are controversial, with studies showing differing results depending on testing design.[70,74-76] However, 3 recent biomechanical studies have shown agreement that anteroinferior plate placement leads to greater resistance to cantilever bending.[70,74,76]

Studies conducted on plate fixation have demonstrated good results. Shen et al[77] reported a 97% union rate and 94% satisfaction rate postoperatively in 232 midshaft clavicle fractures. Robinson et al[60] demonstrated significantly lower nonunion rates and low complication rates with ORIF as compared with nonoperative treatment for displaced midshaft clavicle fractures. Similarly, Duan et al[2] found lower rates of malunion and greater patient satisfaction with ORIF compared with nonoperative treatment for midshaft clavicle fractures. Furthermore, a 2012 meta-analysis of 6 RCTs and more than 400 patients found that operative treatment (plate or intramedullary fixation) of displaced midshaft clavicle fractures was associated with lower rates of nonunion and earlier functional return than nonoperative treatment.[59] Some authors have also reported that operative treatment with plate fixation may allow athletes to return to sports earlier, in one case as soon as 13 days.[78] However, a 2014 study of 1350 patients found that nearly 25% of patients who underwent ORIF for a midshaft clavicle fracture required reoperation. The most common reason for reoperation after plate fixation was due to prominent hardware, with females most at risk for this.[21]

Intramedullary Fixation

Intramedullary fixation is a minimally invasive technique best done in the supine or beach-chair position and includes using a small incision along Langer's lines, which causes less soft tissue dissection.[14] This procedure involves drilling a hole into the canal of the clavicle and inserting a pin, which transverses the fracture. The pin is then later surgically removed when healing is confirmed radiographically, which ranges from 2 to 6 months postoperatively.[3,16,22] Historically, this procedure has been shown to have a lower refracture rate, less risk of damaging the supraclavicular nerves, and a faster rate of union. It is also seems to be more stable. In 1975, Neviaser et al[79] reported a healing success rate of 100% using a Knowles pin. In 1980, Zenni et al[80] reported a 100% success rate with a variety of intramedullary fixation techniques. However, in 2001, Grassi et al[81] reported a 35% complication rate amongst great rates of healing; the majority were superficial infections. A more recent study by Strauss et al[82] reported an end union rate of 100% and maintenance of full shoulder range of motion. However, there was a complication rate of 50%. On the contrary, a 2011 meta-analysis reported fewer symptomatic hardware events with intramedullary fixation compared with plating, and intramedullary fixation had a higher union rate and better functional outcomes compared with nonoperative management.[2] Furthermore, a 2012 systematic review found no differences in terms of outcomes or complications between plate and intramedullary fixation for displaced midshaft clavicle fractures.[83]

External Fixation

External fixation may be more effective in cases of open fractures and where union is unable to be achieved.[15,84] This technique involves drilling into uninjured points of the clavicle around the fracture and screwing bolts or wires through the holes. Because there is no stripping of the periosteum in this procedure, there is a lower chance of devascularizing the clavicle, and, due to its cortical structure, the pins anchor to the clavicle well, resulting in increased stability and fast healing.[84] However, due to the nature of the technique, the bolts traverse the skin, possibly increasing the risk of infection. As such, proper pin-site care must be performed. On the other hand, there is easy access to the skin, and a second operation is not required to remove any bolts or pins. When performing external fixation, Schuind et al[84] advocate inserting medial pins from anterior to posterior and lateral pins from superior to inferior. They reported good healing in all 20 patients treated in this manner.[84] Although rarely used in modern practice, external fixation may be indicated in cases of extensive soft tissue injury over the clavicle, patients with severe skin conditions preventing open surgery, or septic nonunions that preclude internal fixation.[84]

Conclusion

Midshaft clavicle fractures are common injuries that can result in inadequate functional results, prolonged pain, or nonunion if treated improperly. Nondisplaced fractures without involvement of surrounding structures should be managed nonoperatively because the complication rates for these fractures have remained relatively low. However, traditional nonoperative management, once based on studies showing low rates of nonunion, has come into question as newer studies trend toward a much higher nonunion rate. Interestingly, nonoperative functional outcomes after successful union have been worse with more recent studies. The reasons for this are likely diverse and include multiple factors such as social expectations and changes in society's ability to tolerate discomfort and pain.

Recent studies show that operative treatment of midshaft clavicle fractures can result in better functional results and patient satisfaction than nonoperative treatment in patients meeting certain criteria. Outside of definite operative indications such as open fracture or neurovascular compromise, the ideal surgical candidate would be a young, healthy, male patient with high functional demands or a desire to return to sports quickly, presenting with a comminuted, displaced, and shortened fracture. The optimal method of surgical treatment, whether by plate fixation or intramedullary fixation, remains a topic of debate because current studies seem to indicate no difference between the methods in terms of functional outcome and complications. This provides an excellent opportunity for prospective RCTs comparing nonoperative, plate, and intramedullary fixation with an emphasis on identifying the patients most likely to benefit from surgery.

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