Midshaft clavicle fractures—when to operate

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Abstract: Midshaft clavicle fractures are some of the most commonly encountered musculoskeletal injuries in orthopaedics. Non-operative treatment for minimally displaced fractures has been widely accepted as the standard of care, while treatment for displaced fractures has remained controversial. However, the last two decades has seen an increase in randomized controlled trials comparing operative and non-operative management of these fractures. Multiple meta-analyses have been performed and demonstrate that operative intervention can significantly reduce the risk of nonunion and improve short-term shoulder function in the appropriate patient. After considering patient comorbidities and functional goals, midshaft clavicle fractures featuring >2 cm of shortening or ≥100% of displacement should be considered for open reduction and internal fixation. Re-operation rates for implant removal remain high, and patients should be counseled appropriately when considering surgical management.

Keywords: Clavicle; midshaft; fracture; surgery; operative *vs.* non-operative

Introduction

The clavicle is one of the most commonly fractured bones in the human body. It has been reported to represent 2.6% to 4% of all adult fractures (1,2). Of these, fractures of the middle-third diaphysis, or midshaft, compose a majority of injuries at 65.4% to 76% of clavicle fractures (2,3). It is well understood that minimally displaced midshaft clavicle fractures often heal well with non-surgical management. Treatment of displaced midshaft clavicle fractures, however, remains controversial. The last two decades have seen an explosion in peer-reviewed literature published comparing the results of operative and non-operative management in these displaced midshaft clavicle fractures. While there are now relatively well-established radiographic parameters to assist in surgical decision-making (4), treatment choice is still often made on a case-by-case basis after incorporating specific fracture characteristics, patient comorbidities, functional level, and activity goals.

The objective of operative intervention in orthopaedics is to maintain or improve a patient's quality of life superior to that of non-operative management. In midshaft clavicle fractures, it is known that nonunions and malunions frequently have detrimental effects on a patient's clinical outcome (4-6). Furthermore, for specific fracture patterns, operative intervention has been shown to be both beneficial and safe (7-9). The aim of this review is to provide clinical guidance in decision-making when treating adult patients with displaced midshaft clavicle fractures.

Anatomy

The clavicle is a tubular osseous structure that connects the sternum to the scapula. It plays a critical role in the formation of the shoulder girdle and superior shoulder suspensory complex. In development, it has one of the longest ossification periods starting at 5–6 weeks gestation and ending in the early twenties. It is described to have two

primary ossification centers (10), one medial and one lateral. They both function through intramembranous ossification, and the medial ossification center is believed to contribute more to overall length (10). A 2009 radiographic study by McGraw *et al.* found that 80% of adult clavicular length was achieved by age 12 years in males and age 9 years in females (11). By adulthood, the average clavicular length is around 160 mm (12). The left clavicle is typically 1–4 mm longer than the right, but the right is more robust (13,14). It is estimated that up to 28% of individuals may have clavicular asymmetry of ≥5 mm (13). This is important to consider clinically when using contralateral clavicular length as a baseline to assess shortening.

The clavicle's location and position make it prone to injury, as it is the primary anterior strut to lateral compressive forces through the shoulder. Its thin and tubular shape through the middle-third make this area more prone to fracture (15). Biomechanical studies suggest that the middle-third aspect is particularly vulnerable when compressive loads are transmitted through its long axis (16). This type of load is commonly experienced, as individuals tend to land on their shoulder after a fall in an effort to protect the head. These characteristics contribute to the high incidence of midshaft clavicle fractures in musculoskeletal medicine.

History & physical exam

Approximately 90% of clavicle fractures are due to a direct blow to the shoulder (17). A thorough history and physical examination are needed to accurately diagnose and treat midshaft clavicle fractures. Patients presenting with paresthesias or weakness of the injured extremity may have a concomitant brachial plexus or vascular injury (18). These associated injuries are relatively rare, but are often seen with scapulothoracic disassociation (19). This is particularly important to consider in the polytrauma patient, as the presence of a clavicular fracture may indicate coexistent thoracic or upper extremity injury (20). In addition to a neurovascular exam, a thorough skin assessment is also needed upon initial evaluation.

Approximately 1.4–2% of clavicle fractures are open fractures (21,22). These are almost exclusively associated with high-energy mechanisms. Skin tenting, however, can also be seen even with lower energy trauma. If the integrity of the skin is compromised due to pressure from an underlying fracture fragment, the risk of progression to an open fracture is not negligible (23). In one study,

vertical butterfly fracture fragments reportedly caused skin compromise in 8.5% of patients undergoing early surgical intervention for midshaft clavicle fractures (24). Vertically oriented fracture fragments can be assessed on radiographs. Imaging should be performed after a thorough history and physical examination are complete.

Imaging and fracture classification

Plain radiographs are the imaging modality of choice for initial assessment of midshaft clavicle fractures. Recent literature has suggested that upright films are necessary, as supine films may underestimate the true amount of displacement and shortening of the fracture (25). Computed tomography (CT) likely provides a more accurate method of measurement, but this is typically reserved for complex fracture patterns or polytrauma patients with concomitant injuries (26). Recommended radiologic views include a traditional posteroanterior thorax view as well as a 15–20° cephalic tilt view of bilateral clavicles (25-28).

Multiple classification systems have been developed utilizing radiographic characteristics of these fractures. Two of the most popular include the Allman and Robinson classification systems. The Allman classification system divides the clavicle into 3 equal thirds (29). The Robinson classification divides the clavicle into fifths, but then joins the 3 central fifths into a uniform "middle" segment (30). This effectively captures the entire diaphysis in its "type 2" pattern, which may be important as a recent study found that the Robinson classification system had an improved prognostic ability compared to other systems (31). This, however, has not been widely validated, and a commonly accepted classification system to predict prognosis and necessity of surgical management is still lacking. Thus, descriptive characteristics such as fracture location (i.e., midshaft), displacement, and shortening have been the mainstays of evaluating these injuries to predict need and benefit of operative treatment.

Accurate assessment of radiographic displacement and shortening is critical when determining treatment options. Multiple techniques have been described to measure shortening after a midshaft clavicle fracture (28). Overlap of fracture fragments, as well as overall length between the two clavicles, have both been described as methods to quantify fracture shortening. A 2008 radiographic study published in the *Journal of Orthopaedic Trauma* found that comparing overall clavicular length between fractured and non-fractured sides was the most accurate technique
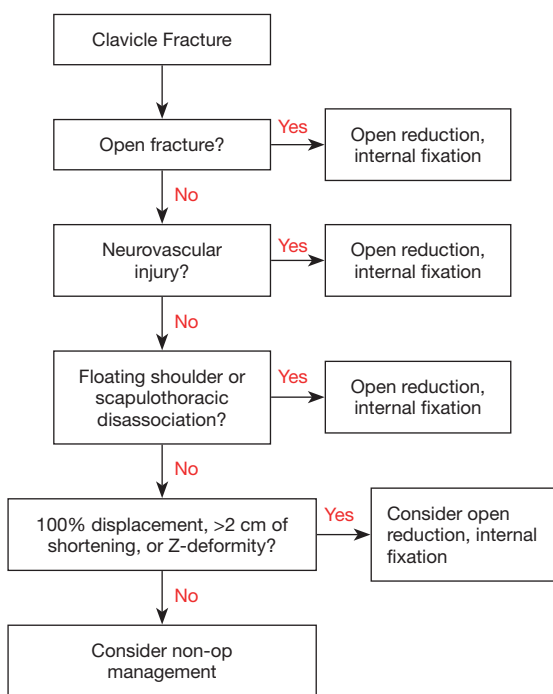
Figure 1 Flow-chart depicting basic algorithm for operative decision making when treating adult midshaft clavicle fractures.

when using CT as a standard (28). In particular, an upright posteroanterior thorax radiograph with full view of both clavicles was found to be the best medium in which to measure shortening. A standard radiograph of the fractured clavicle alone tended to overestimate the amount of shortening by approximately 6 mm when compared with the other techniques (28).

Treatment

Until recently, traditional treatment for midshaft clavicle fractures has been non-surgical. Neer published a series in 1960 of over 2,000 clavicle fractures treated non-operatively and found only a 0.13% nonunion rate (5). More recent literature, however, has found this number to be much higher, reaching up to 15% in some studies (4,32). Fracture displacement is a critical component of non-union risk, as minimally displaced fractures have been shown to heal well with non-surgical treatment.

Non-operative

The standard of care for minimally displaced, closed, midshaft clavicle fractures without associated neurovascular injury is non-surgical treatment (33). The two primary options for non-surgical treatment include sling immobilization or figure-of-eight bracing. A recent Cochrane meta-analysis compared figure-of-eight bracing versus sling use for non-surgical treatment of midshaft clavicle fractures (34). Only three randomized controlled trials met inclusion criteria, and unfortunately these were found to be either underpowered or at high risk of bias. The authors concluded that there was insufficient evidence to recommend one treatment method over the other (34). It is worth noting, however, that the most recent of these trials (Ersen *et al*. 2015) found significantly increased rates of pain in the early treatment period and an average of 1.5 mm of fracture shortening with figure-of-8 bracing compared to sling use (35). The authors of this review prefer to use sling immobilization with range of motion limited to pendulum exercises for the first 2 weeks after injury. Overhead motion and gradual weight bearing typically start at 4–6 weeks depending on the patient's symptoms.

Operative

Operative treatment for adult midshaft clavicle fractures has seen a rise in recent decades. In significantly displaced fractures, or fractures that are open or associated with neurovascular injury, operative treatment is indicated (*Figure 1*). Evidence has shown that operative management, particularly plate and screw fixation, reduces the risk of nonunion and improves short-term overhead function in adult patients when compared to non-operative management. The radiographic parameters of >2 cm shortening and ≥100% of displacement popularized by Hill and Nowak *et al*. (4,6) are now relatively well-accepted radiographic indications to consider operative management. In 1997, Hill *et al*. published a prospective case series following 52 patients over 38 months and found that initial shortening of ≥20 mm was highly predictive of unsatisfactory results. All six patients with >20 mm of initial shortening went on to nonunion, which was found to be highly significant (P<0.0001) (4). Of these patients with nonunion, over 85% had persistent symptoms including pain or difficulty with heavy lifting (4). This study, along with others, popularized the notion that displaced midshaft clavicle fractures do poorly without surgery. This led to a new interest in randomized controlled trials comparing the two treatments.

In 2007, the *Canadian Orthopaedic Trauma Society* (COTS) published a randomized, multi-center trial
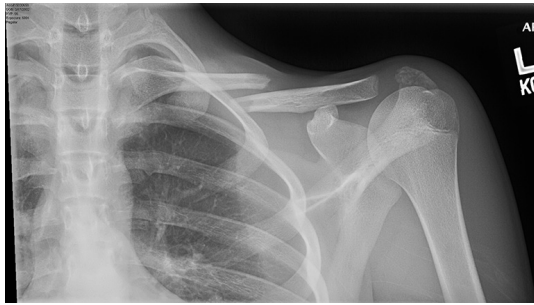
Figure 2 Radiograph of a 17-year-old male with a left midshaft clavicle fracture demonstrating 100% displacement and approximately 2 cm of shortening.

comparing non-operative treatment with plate and screw fixation for displaced midshaft clavicle fractures (7). This was a landmark study as it was one of the first to use a prospective, well powered, randomized data-set to compare these two widely used treatment modalities. Between 2001 and 2004, 111 patients were enrolled and followed for a minimum of 1 year. Patients were randomized to the operative (n=62) or non-operative treatment (n=49) arms at time of evaluation in the Emergency Department. The inclusion criteria consisted of middle third fracture location, complete fracture displacement (defined as no cortical contact between the main proximal and distal fragments), age between 16–60 years, and no medical contraindications to general anesthesia. Operative fixation was performed using small-fragment instrumentation with a superior plating technique. Non-operative treatment was performed using sling immobilization for 6 weeks (although the authors admit compliance was variable). Patients were then assessed at 6-, 12-, 24-, and 52-week time intervals. The results showed that the operative group had significantly superior Constant shoulder scores and DASH scores at all time-points including up to 1 year (P<0.01). Patients were subjectively more satisfied with their shoulder in the operative group (odds ratio of 3.5 to answer "*yes*" when asked "*are you satisfied with your shoulder?*" compared to the non-operative group at 1 year) and there were no significant losses of range of motion in either group. Time to radiographic union was statistically significant between the two groups with an average of 16.4 weeks in the operative group and 28.4 weeks in the non-operative group (P=0.001). Complications and adverse events were also reported and included: nonunion, malunion requiring further treatment, wound infection or dehiscence, hardware irritation requiring removal, complex regional

pain syndrome, surgery for impending open fracture, transient brachial plexus symptoms, acromioclavicular or sternoclavicular joint abnormality, early mechanical failure, and "other". Complication rates at 1 year were 37% in the operative group and 63% in the non-operative group, which was statistically significant (P=0.008). The results of this trial demonstrated that completely displaced midshaft clavicle fractures benefit from early operative fixation in regards to functional, cosmetic, and radiographic outcomes. An example of a completely displacement (and shortened) fracture pattern is demonstrated in *Figure 2*. This patient went on to be successfully treated with open reduction and internal fixation using a superior plating technique.

Since the COTS trial, there have been multiple other randomized controlled trials performed in recent years comparing operative with non-operative treatment. Subsequently, multiple meta-analyses have been performed providing comprehensive assessments of these trials based on varying inclusion criteria. In a 2017 *Journal of Bone and Joint Surgery* (JBJS) meta-analysis, Woltz *et al.* found that patients treated with plate and screw fixation had an 84% reduced risk of non-union compared with the non-operative group [relative risk (RR) =0.14; 95% confidence interval (CI), 0.06 to 0.32]. Secondary operation rates were insignificantly higher in the operative group at 17.6% compared to 16.6% in the non-operative group. Additionally, functional outcome scores were not significantly different between groups (8). In a more recent meta-analysis from the *Journal of Orthopedic Trauma*, patients that underwent operative fixation had a nonunion rate of 1.7%, compared with 14.5% nonunion rate in the non-operatively treated patients (36). Increased short-term (<6 months) improvements in the Constant and DASH functional scores were also seen in the operative compared to non-operative group. Mean Constant scores at 3-month follow-up were significantly higher in the operative group at 84.6 compared to 81.7 in the non-operative group. DASH scores at the same time interval were also improved in the operative group at mean of 6.4 compared to 10.1 in the non-operative group. Regarding secondary operation, including elective symptomatic implant removal, this analysis showed decreased rates in the operative group (risk ratio 0.88) (35). Two other recent meta-analyses have also published similar findings (37,38). One such study also commented on appearance dissatisfaction rates and found a significantly lower rate in the operative patients (risk ratio 0.35, P<0.001) (37). These recent meta-analyses summarize a large portion of the available high-level evidence comparing

Figure 3 Radiograph of a 30-year-old male with a well-healed left midshaft clavicle that previously demonstrated 100% displacement and z-deformity.

operative versus non-operative management for displaced midshaft clavicle fractures in adults. In the correct patient, operative intervention can improve union rates, functional outcomes, and cosmetic appearances when compared to non-surgical management. Specific operative treatment type (i.e., superior plating *vs.* anterior plating *vs.* intramedullary fixation) remains controversial. In Wiesel *et al.*'s 2018 *Journal of the American Academy of Orthopaedic Surgeons* (JAAOS) systematic review, intramedullary nail fixation (IMN) was suggested to be biomechanically inferior to superior plate fixation and re-operation rates for hardware irritation were anywhere from 26–41% higher in the IMN group when compared to the plating group (39). While superior plating is an excellent treatment option, re-operation rates after all types of fixation remain high, and patients should still be well informed of the surgical risks prior to selecting operative management. Additionally, even fractures with significant displacement and z-deformity can go on to heal well without surgery (*Figure 3*), and thus patients should be well informed prior to making a final decision.

Conclusions

Operative fixation of adult midshaft clavicle fractures has been shown to be safe and efficacious when used in the correct patient. Patients with significant fracture shortening (>2 cm), displacement (≥100%), or z-deformity may have functional benefits in the early post-operative period (≤1 year) when treated with open reduction and internal fixation. Ultimately, further research is needed to definitively determine which treatment modality is superior in managing adult patients with displaced midshaft clavicle fractures.

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Footnote

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