Surgical Management of Humeral Shaft Fractures – What is the Best Choice?

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Introduction

Humeral shaft fractures account for 5% fractures in the United States [1]. They occur frequently in both young males in their second and third decades, and elderly females, typically due to high velocity trauma and falls respectively [2]. These fractures may be treated non-operatively or operatively. Most fractures are treated non-operatively with functional bracing, as fracture alignment of up to 20 degrees of anterior bowing and 30 degrees of varus is accepted for functional bracing [3].

The relative and absolute indications for surgery over conservative management include radial nerve palsy, vessel injury, segmented fractures, soft tissue damage, and loss of reduction, non-union, or pathologic fractures [4,5]. Current operative options include intramedullary nailing (IMN), open-reduction and internal fixation (ORIF), and minimally invasive plate osteosynthesis (MIPO). While IMN and ORIF are well-established approaches, MIPO is a relatively new approach. This article will explore which approach is the best-treatment option for patients requiring operative management for humeral fractures.

Anatomy

The humeral shaft is home to a complex anatomy as several key nerves and vessels course near the shaft to innervate and perfuse structures of the lower arm and hand. Of particular vulnerability in humeral shaft fractures are the radial, lateral antebrachial cutaneous and posterior antebrachial cutaneous nerves [6]. While damage to the cutaneous nerves would present as loss of sensation of the arm, damage to the radial nerve is arguably more serious, presenting with wrist drop due to lack of innervation to the extensors of the wrist, hand, and fingers.

Indications for Surgery

Non-surgical functional bracing is the treatment of choice in simple, closed diaphyseal fractures, however, if the proximal or middle third of the diaphysis is involved, surgical treatment options should be considered due to concern for non-union [7]. Especially in the unstable midshaft transverse fracture pattern. Surgery is also indicated over functional bracing in the setting of severe neurovascular injury, concurrent ipsilateral forearm fractures, high grade open fractures, and pathologic fractures [8].

Treatment Options

The conventional surgical treatment options for humeral shaft fractures include IMN and ORIF. In recent years, MIPO has become another viable treatment option for surgical management of these humeral shaft fractures. ORIF was the original approach for the treatment of humeral shaft fractures. The procedure may be performed by an anterolateral approach or a posterolateral approach. In the anterolateral approach, the biceps muscle is split and the radial nerve is largely spared as it is posterior to the intermuscular septum and thus is not typically exposed [4,9]. As a result, this method is preferred to the posterolateral approach in which the medial head of the triceps is split and the radial nerve is regularly exposed therefore subject to intraoperative traction or potential injury.

IMN was initially used for the management of femoral fractures with great success. Because of this, it later became a more common treatment for humeral fractures as it is a relatively less invasive procedure with a smaller area of tissue exposed, preserved fracture biology, and load sharing [10]. IMN has been recommended as the treatment of choice in those with pathologic fractures secondary to poor bone quality, such as the elderly, due to it load-sharing properties [10].

MIPO is the newest approach to humeral shaft fractures. It is theoretically the most favorable of the approaches, as it involves the smallest incision and least amount of stripping of the surrounding soft tissues and periosteum, with the lowest risk of infection or injury to the neurovascular structures [9].

Outcomes

In this literature review, the most commonly encountered outcomes of surgical treatment of humeral shaft fractures included non-union, delayed union, radial nerve palsy, infection, impingement, and motion restriction. Some other less frequently encountered complications and poorer outcomes included re-operation, intraoperative blood loss, and increased operative time. Most studies compared IMN to ORIF as such are the conventional methods. Five studies compared MIPO to ORIF, and two studies compared MIPO to both ORIF and IMN.

Non-union

The rates of nonunion following humeral fractures are mixed when comparing IMN to ORIF. The literature has suggested that IMN has higher rates of nonunion as compared to ORIF [11,12]. Davies G, et al. observed that of 15 patients in the IMN group, four experienced nonunion while only 1 of the 15 MIPO patients demonstrated nonunion. Additionally, some studies have indicated that there is no significant difference in rates of nonunion between the two approaches [13] or as compared to MIPO [14,15]. The meta-analysis by OuYang et al. pooled data from 10 RCTs with a total of 18 out of 217 patients in the IMN group, and 15 out of 222 patients in the ORIF group experiencing nonunion; this difference was non-significant. Similarly, Zhao J, et al. pooled results from 15 RCTs and two semi-RCTs and no significant difference in nonunion among the
three techniques was found. The meta-analysis by Qiu H, et al. [15] agreed with Zhao's results; after pooling results from 17 RCTs no significant difference was found among MIPO vs. IMN vs. ORIF.

**Delayed Union**

Similarly, results of the rates of delayed union among the different approaches have also been mixed, with the majority of studies showing no difference between conventional techniques or among conventional techniques vs. MIPO [13,15,17–19]. When a difference was detected, IMN typically demonstrated poorer rates of delayed union [8, 20–22]. Li Y, et al. [23] noted one episode of delayed union in the IMN group (45 patients), and 2 episodes of delayed union in the ORIF group, however this difference was determined to not be statistically significant. Similarly, according to Fan et al., the average union time was 6.7 weeks in the IMN group (30 patients) and 10.6 weeks in the ORIF group (30 patients); this result was statistically significant.

The rates of non-union or delayed union may also be influenced by external factors that contribute to poor wound healing such as older age, obesity, poor nutrition, and corticosteroid use, as well as the fracture pattern, concurrent infections, and inadequate immobilization [24]. The higher rates of delayed union seen in IMN may be due to greater incidence of distraction in such cases [25].

**Iatrogenic Radial Nerve Palsy**

The radial nerve is at high risk of injury in humeral fractures, on its course to the hand. Palsy of the nerve may occur due to entrapment, contusion or laceration. Fractures of the middle and mid-distal shaft are particularly at risk for non-iatrogenic radial nerve palsy, especially with transverse or spiral fractures [26].

MIPO has typically demonstrated the lowest incidence of iatrogenic radial nerve palsy as compared to either IMN or ORIF [15,18,19,27]. The meta-analysis by Hohmann E, et al. which compared 8 randomized prospective studies indicated that the conventional techniques (IMN/ORIF) had significantly higher numbers of nerve injuries as compared to MIPO (OR = 0.302, 95% CI, 0.109-0.836, p = 0.021). Three studies reported ORIF as having the greatest rate of radial nerve palsy when compared to either IMN or MIPO [17,18,28], while two papers noted that IMN had higher rates than ORIF [11,29]. Gottachalk MB, et al. for example, used the American Board of Orthopedic Surgery (ABOS) operative database to explore the complications, functional outcomes, and management trends of humeral shaft fractures from 2003 to 2014. According to their research, iatrogenic radial nerve palsies occurred at a rate of 3.1% in the IMN group (24516 patients) versus 7.8% in the ORIF group (24515 patient), (p = 0.001). Davies et al. 2016 reported radial nerve palsy occurring at a rate of 20% in their IMN group, and 0% of their MIPO group, however their sample size was much smaller with only 15 patients per group.

It is likely that MIPO has the lowest rates of radial nerve palsy as compared to IMN or ORIF as the anterior MIPO technique involves the most minimal exposure of the nerve during surgical manipulation. IMN is comparably better than ORIF as it is minimally invasive. Additionally, the posterior approach commonly used in ORIF creates the greatest exposure of the nerve for potential injury [11]; this posterior approach is not used in either MIPO or IMN.

**Restricion**

IMN consistently had the worst outcomes for shoulder stiffness when compared to ORIF or MIPO [13,14,30,31]. The systematic review by Zhao J, et al. which compared meta-analyses by Ouyang H, et al. and Ma J, et al. found that IMN had higher rates of shoulder impingement resulting in greater restriction of movement. This restriction is typically due to rotator cuff impairment caused by the entry point of the nail. Both iatrogenic subacromial stiffness and cuff weakness secondary to cuff tear are both possible.

**Infection**

Infection is most commonly associated with ORIF procedures, as compared to IMN or MIPO [17,18,20,28]. Hu X, et al. performed a meta-analysis comparing 8 studies (4 RCTs, 2 prospective cohorts and 2 retrospective cohorts), and determined that infection was one of the IMN consistently had the worst outcomes for shoulder stiffness when compared to ORIF or MIPO [13,14,30,31]. The systematic review by Zhao J, et al. which compared meta-analyses by Ouyang H, et al. and Ma J, et al. found that IMN had higher rates of shoulder impingement resulting in greater restriction of movement. This restriction is typically due to rotator cuff impairment caused by the entry point of the nail. Both iatrogenic subacromial stiffness and cuff weakness secondary to cuff tear are both possible.

**Other (intra-op blood loss, op time, etc.)**

Fan Y, et al. reported higher intra-operative blood loss in patients undergoing ORIF versus IMN, likely due to greater soft-tissue exposure [12]. They found that of the 30 patients per group (IMN vs. ORIF), the mean intraoperative blood loss for IMN was 59.03 +/- 9.41mL and was 150.23 +/- 11.77mL for ORIF (p < 0.001). Fan also found that the IMN procedure was significantly shorter (58.53 +/- 6.25 min) than the ORIF procedure (90.93 +/- 45.6min). The more recent study by Hu et al. 2016, however, noted no significant difference in operative times among MIPO vs. ORIF vs. IMN.

While the MIPO technique consistently demonstrates fewer complications as compared to conventional techniques and involves a smaller incision with less scarring, it has been shown to result in greater rates of malrotation than the other approaches [17,32]. The prospective cohort study by Esmailieh et al. 2015 noted 6 of 32 patients that underwent MIPO (18.7%) and 2 of 33 patients that underwent ORIF demonstrated varus degree of deformity greater than 5 degrees. Similarly, a prospective cohort by Wang et al. 2015 reported that postoperative malrotation of greater than 20 degrees occurred at a rate of 40.9% (9 of 22 cases) in the MIPO group as compared to 0% (0 of 23 cases) in the ORIF group. Such malrotation may subsequently cause secondary degenerative arthritis.

**Functional outcomes**

The UCLA scale, American Shoulder and Elbow Surgeons standard assessment form (ASES), and Constant score (CS) were the functional outcomes seen most frequently in the literature. Pain, Activities of daily living, range of motion, and strength are the 4 components of the CS [33]. The ASES score evaluates activities of daily living and a patient self evaluation [33], while the UCLA scale incorporates both active shoulder elevation and strength, as well as satisfaction, function, and pain [34].

IMN consistently had the worst Constant scores in multiple papers [4,12,20,21]. Similarly, IMN also typically rated worse than ORIF on ASES scores [12,21]; however one study found no difference between ASES scores in IMN versus ORIF [29]. Interestingly, despite the lower rate of complications in MIPO technique, several reports noted no difference in UCLA scores between MIPO and conventional studies [18,35].
Recommendations/Conclusions

According to the literature review, MIPO should be the first line technique for surgical treatment of humeral shaft fractures. It consistently ranks the lowest in complication rates, such as non-union, radial nerve palsy, and infection. The most significant drawback to MIPO is the higher incidence of malrotation when compared to conventional techniques; however, more research is needed to better evaluate the clinical implications of this malrotation.

If deciding between the two different conventional approaches, the results of ORIF typically outperform those of IMN, with lower incidence of complications with the exception of radial nerve palsy. Evidence of the declining favor of IMN has been shown by Gottschalk et al 2016, with significant declines in IMN as treatment for humeral fractures from 2003 to 2014. They attribute the decline in use of IMN due to higher overall morbidity and pathologic factors, despite lower rates of iatrogenic nerve palsies and infections, as compared to ORIF [28].

The mixed results of the functional outcomes of the three approaches suggests that all three are valid methods in the surgical treatment of humeral shaft fractures. When consider which approach will have the overall most favorable outcomes for the patient, however, the MIPO approach with its fewest complications and best aesthetic result, is clearly preferable.

References


