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## ORIGINAL ARTICLE

# Open reduction–internal fixation versus intramedullary nailing for humeral shaft fractures: an expected value decision analysis

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**Background:** Previous randomized controlled studies and meta-analyses have failed to collectively favor either open reduction–internal fixation (ORIF) or intramedullary nailing (IMN) fixation. The purpose of our investigation was to elucidate the optimal decision between ORIF and IMN for acute traumatic operative humeral shaft fractures through an expected value decision analysis.

**Methods:** We performed an expected value decision analysis and sensitivity analysis to elucidate the difference between ORIF and IMN fixation for patients with acute traumatic humeral shaft fractures. We surveyed 100 consecutive, randomly selected volunteers for their outcome preferences. Outcomes included union, delayed union, major complications, minor complications, and infection. A literature review was used to establish probabilities for each of these respective outcomes. A decision tree was constructed and a fold-back analysis was performed to find an expected patient value for each treatment option.

**Results:** The overall patient expected values for ORIF and IMN were 12.7 and 11.2, respectively. Despite artificially decreasing the rates of major complications, infection, delayed union, and nonunion each to 0% for IMN fixation (sensitivity analysis), ORIF continued to maintain a greater overall patient expected value (12.7 vs. 11.4, 11.2, 11.2, and 12.1, respectively). Only if the rate of nonunion after ORIF was increased from 6.1% to 16.8% did the overall expected outcome after ORIF equal that of IMN (11.2).

**Conclusion:** Our expected value decision analysis demonstrates that patients favor ORIF over IMN as the optimal treatment decision for an acute traumatic humeral shaft fracture.

**Level of evidence:** Level III; Economic and Decision Analysis Study

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**Keywords:** Humerus fracture; decision analysis; diaphyseal humerus fracture; fracture fixation; plating; intramedullary nail

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Humeral shaft fractures are relatively common and account for nearly 3% of all orthopedic injuries.<sup>35,40,41</sup> The majority of humeral shaft fractures can be treated nonoperatively, with closed treatment resulting in a predictably high rate of union and functional outcome.<sup>1,22,32,38,40,42</sup> Operative management of humeral shaft fractures is often reserved for open fractures, polytrauma, ipsilateral brachial plexus injuries, floating elbow,

or inability to maintain adequate reduction and alignment at the fracture site.<sup>11,28,40</sup>

Definitive operative intervention for acute traumatic humeral shaft fractures generally consists of either open reduction with internal fixation (ORIF) or antegrade intramedullary nailing (IMN). Investigations have found similar union rates and functional outcomes after ORIF vs. IMN but with marginally greater overall complications after IMN.<sup>11,12,15,28,29,35,40,41</sup> ORIF provides for anatomic reduction, absolute stability, and no increase in shoulder pain.<sup>15,27-29,35,39,41</sup> However, disadvantages result from disruption of the soft tissue envelope, increasing the potential for nonunion, infection, and, more commonly, iatrogenic radial nerve palsy.<sup>28,40,41</sup> Conversely, IMN is associated with more limited surgical dissection and increased biomechanical strength but at the increased risk of iatrogenic intra-articular shoulder injury.<sup>12,38,40</sup>

Despite the extensive literature comparing outcomes after ORIF and IMN for acute humeral shaft fractures, the superior treatment strategy remains controversial. Expected value decision analysis is a validated tool that has been used to evaluate competing treatment options in complex medical decision-making scenarios such as this.<sup>7,23,31,36</sup> By this method, clinical evidence to include probabilities of various outcomes after different procedures that are pooled through a review of the literature is combined with patient value (utility values assigned to the various outcome probabilities indicating the degree to which the patient does or does not desire a specific outcome), yielding a quantitative overall expected value for each of the opposing clinical scenarios. A sensitivity analysis is then performed to discern the threshold for selecting a specific treatment.

The purpose of our investigation was to elucidate the optimal decision between ORIF and IMN for acute traumatic operative humeral shaft fractures through an expected value decision analysis. The null hypothesis is that there is no difference in the overall expected value for ORIF and IMN surgical fixation for humeral shaft fractures.

## Methods

We applied the standard 5-step expected value decision analysis, comprising (1) establishment of a decision tree, (2) determination of the respective pooled outcome probabilities, (3) assignment of patient outcome utility values to each outcome probability, (4) fold-back analysis to ascertain overall expected values for each clinical scenario, and finally (5) sensitivity analysis. This methodology has been previously validated and used in the analysis of various orthopedic scenarios.<sup>6,7,23,31,36</sup>

### Step 1: creation of a decision tree

We first created a decision tree to assess ORIF vs. IMN fixation of humeral shaft fractures. For each scenario, outcomes of interest were established: union, delayed union, major complications, minor

complications, infection, and a state of wellness (Fig. 1). Union was defined as all patients who went on to fracture union within the respective study period. The determination of delayed union was made on the basis of the methodology defined for each individual study. Minor complications were those in patients who had any unexpected outcome that did not require reoperation, including transient nerve palsy, shoulder impingement, adhesive capsulitis, and shoulder or arm pain. Major complications were those in patients who required repeated surgery for any cause or had permanent nerve palsy. Infection was defined independently of the other complications and included all deep infections diagnosed within the study period. Finally, the well category comprised all patients who went on to obtain uneventful union in the absence of any of these complications.

### Step 2: establishment of outcome probabilities

We performed an extensive review of the literature through the PubMed, MEDLINE, and Cochrane databases (1980-2015) to determine outcome probabilities. Search terms in various combinations of the following were used to identify primary research articles: "humerus fracture," "midshaft humerus fracture," "diaphyseal humerus fracture," "humerus fracture intramedullary nail," and "humerus fracture open reduction-internal fixation." Inclusion criteria were applied to all articles that involved either ORIF or IMN fixation of operative humeral shaft fractures (open or closed), had peer-reviewed level I to IV evidence, were published in the English language, and included discussion of the aforementioned outcomes of interest for those injuries that underwent ORIF, IMN fixation, or both for all fracture patterns involving the shaft of the humerus. Articles were excluded that involved proximal or distal humeral fractures, pathologic fractures, non-skeletally mature fractures, external fixation, and retrograde IMN fixation or if the cohort was mixed and the outcomes of the included subgroups could not be isolated from the overall cohorts. The references of each article were further reviewed, and additional articles that were not revealed on the initial query were subsequently obtained for further review. Once the individual probabilities for each of the outcomes were extracted from the constituent articles, the probabilities were pooled to generate overall probabilities for each.

### Step 3: determination of patient outcome utilities

A consecutive 100 randomly selected volunteer patients were surveyed for their outcome preferences. Patients were excluded if they were <18 years of age or if they previously had undergone or currently were undergoing treatment of a humeral shaft fracture. Each volunteer was given a questionnaire with a brief basic description of the pathologic process in question as well as of each of the outcomes of interest and was not permitted to consult with a physician before completion of the survey. Patients were then asked to rate their preference, or to ascribe a utility value, to each outcome based on the pooled frequencies generated as previously mentioned. Rating was performed by means of a standard visual analog scale (range 0-10, 0 corresponding to the lowest desire for the perceived outcome and 10 to the highest). The utility values for each category were then averaged to generate an overall patient utility value for each respective outcome.

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