http://dx.doi.org/10.2106/JBJS.17.00181

Appendix

Methodologies

Systematic Review

We utilized the PubMed interface to search the MEDLINE database. The search terms were grouped into 2 broad categories: [Distal radius fractures] and [Fixation method]. The search build for distal radial fractures included: ((distal[All Fields] AND ("radius fractures"[MeSH Terms] OR ("radius"[All Fields] AND "fractures"[All Fields]) OR "radius fractures"[All Fields]) OR "Colles fracture"[All Fields])). The search build for each fixation method was the following: ((closed[All Fields] AND reduction[All Fields] AND percutaneous[All Fields] AND pinning[All Fields]) OR ((Kirschner wire[All Fields] OR Kirschner[All Fields]) AND (fixation[All Fields] OR percutaneous[All Fields]))) for closed reduction and percutaneous pinning; (external[All Fields] AND fixation[All Fields]) for external fixation; and (((("open fracture reduction"[MeSH Terms] OR ("open"[All Fields] AND "fracture"[All Fields] AND "reduction"[All Fields]) OR "open fracture reduction"[All Fields] OR ("open"[All Fields] AND "reduction"[All Fields]) OR "open reduction"[All Fields]) AND ("fracture fixation, internal"[MeSH Terms] OR ("fracture"[All Fields] AND "fixation"[All Fields] AND "internal"[All Fields]) OR "internal fracture fixation"[All Fields] OR ("internal"[All Fields] AND "fixation"[All Fields]) OR "internal fixation"[All Fields])) OR volar plating[ti] OR palmar plat*[ti] OR "volar locking plate"[ti]) for ORIF. Each fixation method was searched individually with the terms for distal radial fracture, which yielded a total of 1,252 studies, of which 226 were duplicates, therefore resulting in a grand total of 1,026 studies.

These 1,026 studies underwent a rigorous screening process by title and abstract. Our inclusion criteria were a clinical study of closed reduction and percutaneous pinning, external fixation, and/or open reduction and internal fixation methods for operative distal radial fractures across all populations and fracture types; reported postoperative complication and/or reduction loss rates; a randomized controlled trial or prospective study; and reporting in English. If there was any question regarding the inclusion of a study, we retrieved and reviewed the full text of the article in question to determine eligibility. Per the first 2 inclusion criteria, we excluded 83 case reports; 219 nonclinical studies including methodological studies, reviews, meta-analyses, and cadaveric or biomechanical studies; 127 studies that did not focus on distal radial fractures alone; 109 studies that did not specifically analyze operative fixation of distal radial fractures; 162 studies that focused on newer or variant fixation techniques; 15 studies that focused on the elderly population only; 42 studies that focused on the pediatric population only; 167 studies of fixation in specific fracture patterns; 3 studies that failed to show fracture patterns; 17 studies that failed to show clinical complications; 3 studies that included open fractures; and 13 studies whose full texts were not accessible. This resulted in 66 studies that met the first 2 inclusion criteria.

To maximize the quality of literature used to derive parameters for the model, we limited our data abstraction to randomized controlled trials and prospective cohort studies only (the third inclusion criterion). We stratified our 66 studies by level of evidence: 16 Level-I randomized controlled trials, 18 Level-II prospective cohort studies, 20 Level-III retrospective studies, and 9 Level-IV case series. Three studies were determined to be a second publication of the same data

set and were excluded. This resulted in a grand total of 34 Level-I and Level-II studies that were thoroughly reviewed to derive the data input into our model.

Transition Probabilities

We observed that 85% of closed reduction and percutaneous pinning pin-track infections[2-5,28,31,70], 94% of open reduction and internal fixation surgical-site wound infections[4,5], and 94% of external fixation pin-track infections[2,27,29,30,35,71-73] would receive antibiotics. Following antibiotic administration, we observed in the literature that 15% of closed reduction and percutaneous pinning pin infections[2,3,26,28,31,70] and 31% of external fixation pin infections[27,29,30,35,71-73] required subsequent pin or fixator removal. No data were found on the probability of antibiotic failure for surgical-site infections following open reduction and internal fixation for distal radial fractures, so we assumed an antibiotic failure rate of 1.76% from a study on wound-healing complications after open reduction and internal fixation for calcaneal fractures[74].

We assumed that all cases of inflammatory tenosynovitis and tendinitis following surgical fixation would undergo conservative treatment. On the basis of a systematic review that studied the probability of recovery after cortisone injection for tenosynovitis, we estimated that 16% of patients would undergo failed conservative treatment for tenosynovitis or tendinitis following closed reduction and percutaneous pinning and external fixation, requiring an additional methylprednisolone injection[75]. Following open reduction and internal fixation, we observed in the literature that 70% of patients underwent implant removal for tendinitis due to direct implant irritation or subluxation of the tendons over the implant[3,10,15,29,30,32,33,35,37]. We assumed that transition probabilities after revision fixations were identical to those of primary open reduction and internal fixation.

For major orthopaedic complications requiring a surgical procedure, we observed probabilities of surgical failure of 24% for tendon rupture reconstruction[76-81] and 5% for carpal tunnel release[82-89]. For deep infection irrigation and debridement procedures, we estimated a failure rate of 44% based on studies that evaluate surgical effectiveness for wrist septic arthritis[90,91]. We assumed that 100% of patients had successful implant removal for all 3 fixation methods when indicated.

Quality of Life

On the basis of data from total wrist fusion and arthroplasty, quality-of-life values (defined as utilities) of successfully treated minor orthopaedic complications for closed reduction and percutaneous pinning and external fixation were estimated to be equal to the optimal fixation quality-of-life value[92], and failure of treatment resulted in a 3.2% loss in utility from optimal fixation[11,92]. Surgical-site infections for open reduction and internal fixations were estimated to result in a 7.2% drop in utility when treated successfully[93,94] and a further drop of 3.5% when the infection does not respond to initial oral antibiotic treatment[92]. Like closed reduction and percutaneous pinning and external fixation, patients with successfully treated cases of tendinitis following open reduction and internal fixation returned to optimal fixation utilities, but failure of conservative treatment caused an 11% loss in utility given need for implant removal[41]. For nonoperative major orthopaedic complications, we estimated 18% disutility (loss in utility) for complex regional pain syndrome[11] and 13% disutility for nonoperative nerve injuries or carpal

tunnel syndrome[95,96]. For major orthopaedic complications requiring a surgical procedure, we estimated the utility of successful tendon rupture reconstruction to be 0.683[95], successful carpal tunnel release to yield a 10% loss in utility from the baseline carpal tunnel syndrome values above[92,95-100], and successful deep infection debridement to be a return to baseline optimal fixation[92]. Successful implant removal after both closed reduction and percutaneous pinning and external fixation was estimated to be a minimal loss of utility of 0.50%[92], whereas for open reduction and internal fixation, we estimated a 7% loss of utility from plate removal[41]. The composite utility value for each cycle of the suboptimal fixation group due to minor or major complications was the sum total of the product of the individual complication utility values as above multiplied by the relative frequency of each complication. For closed reduction and percutaneous pinning, external fixation, and open reduction and internal fixation, patients who underwent failed corrective surgical procedures for major orthopaedic complications were attributed a quality-of-life utility of 0.5, given the range of disutilities associated with the health states of advanced wrist arthrosis and failed or complicated carpal tunnel releases[99-102].

Costing

We assumed that the costs of treating pin and surgical-site infections would include a 7-day course of 250-mg cephalexin[11]. If antibiotics failed for closed reduction and percutaneous pinning and external fixation, we assumed pin removal for closed reduction and percutaneous pinning and external fixation; for open reduction and internal fixation, we assumed operative implant removal, debridement and irrigation, intravenous antibiotics, external fixation, and an additional open reduction and internal fixation[49,50,52,103]. Costs of treating tendinitis or tenosynovitis conservatively included thumb spica or wrist casting, nonsteroidal anti-inflammatory medications, and a single methylprednisolone injection up to 40 mg[103-105]. For closed reduction and percutaneous pinning and external fixation, failed tenosynovitis treatment required an additional methylprednisolone injection; for open reduction and internal fixation, failed tendinitis treatment required plate removal. Costs of treating complex regional pain syndrome included a 1-year course of 100-mg gabapentin and outpatient occupational therapy for desensitization. Costs of treating nonoperative nerve injuries or conservatively treated carpal tunnel syndrome included hand or wrist orthosis with a single injection of methylprednisolone up to 40 mg[104,105].

Analysis

Quality-of-Life Sensitivity

From the health-care perspective, if quality of life after open reduction and internal fixation were valued 7.8% higher at $50,000 willingness to pay or 4.4% higher at $100,000 willingness to pay, then open reduction and internal fixation becomes the preferred method. The societal perspective is more sensitive to the quality-of-life difference: if the quality of life after open reduction and internal fixation were valued 0.8% or 1.2% more, open reduction and internal fixation becomes the preferred option at $50,000 willingness to pay for 0.8% and $100,000 willingness to pay for 1.2%. Other quality-of-life values did not alter the base case results when varied 50% above and below the base value.

Probabilistic Sensitivity

Figure E-1 depicts the probabilistic sensitivity analysis from the health-care perspective. Figure E-2 similarly depicts the probabilistic sensitivity analysis from the societal perspective.

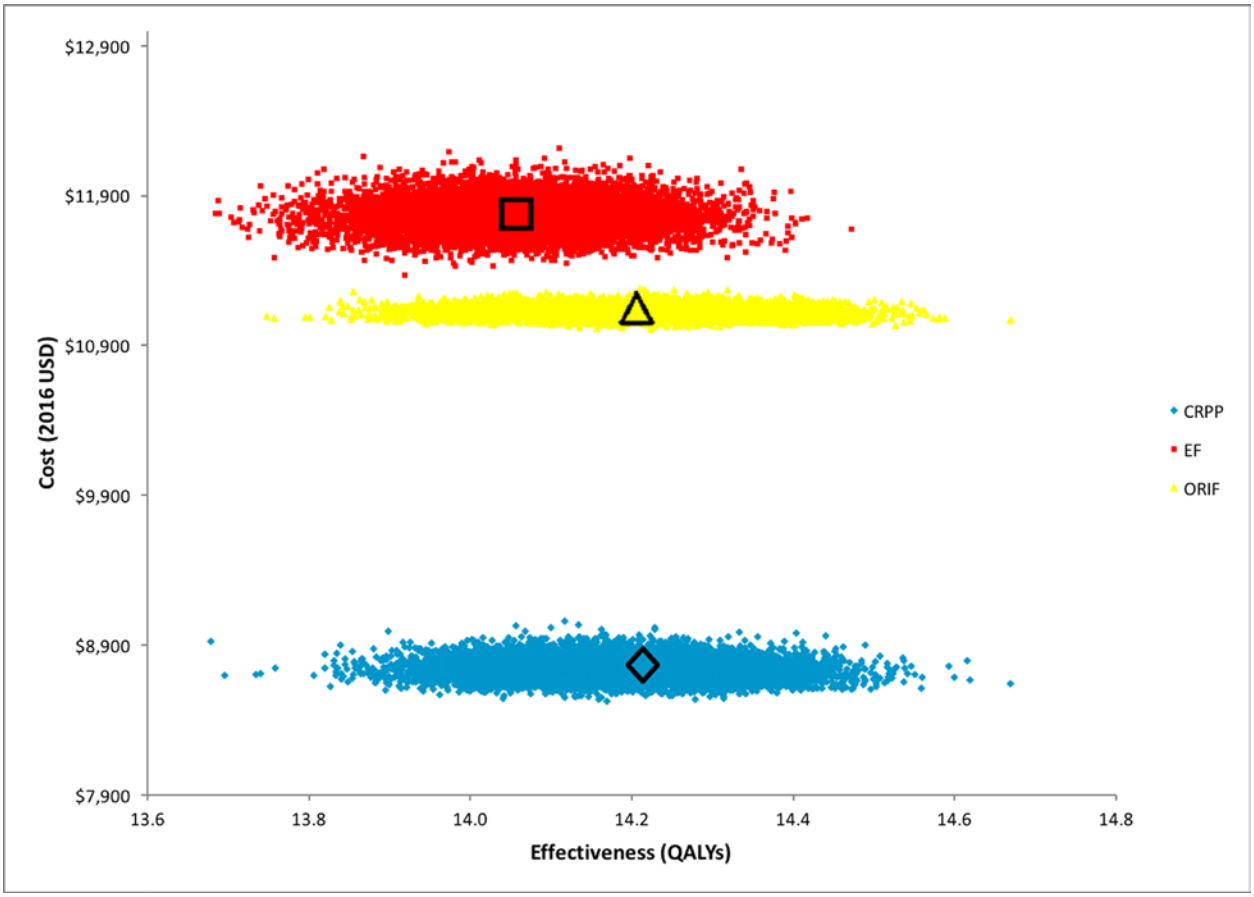

Fig. E-1: Probabilistic sensitivity analysis scatterplot illustrating the cost-effectiveness results of 10,000 iterative runs from the health-care sector perspective that incorporates uncertainty around multiple parameters: probability of reduction loss, probability of major (nonoperative) complications, probability of plate removal for tendinitis after open reduction and internal fixation (ORIF), quality of life 1 year after optimal fixation, and the period of time affecting the quality of life after fracture and its fixation. The mean cost-effectiveness results are represented by the large diamond for closed reduction and percutaneous pinning (CRPP), by the triangle for ORIF, and by the square for external fixation (EF). ORIF was not cost-effective as it was, on average, costlier ($11,123 compared with $8,738) for roughly the same effectiveness (14.2 QALYs).

http://dx.doi.org/10.2106/JBJS.17.00181

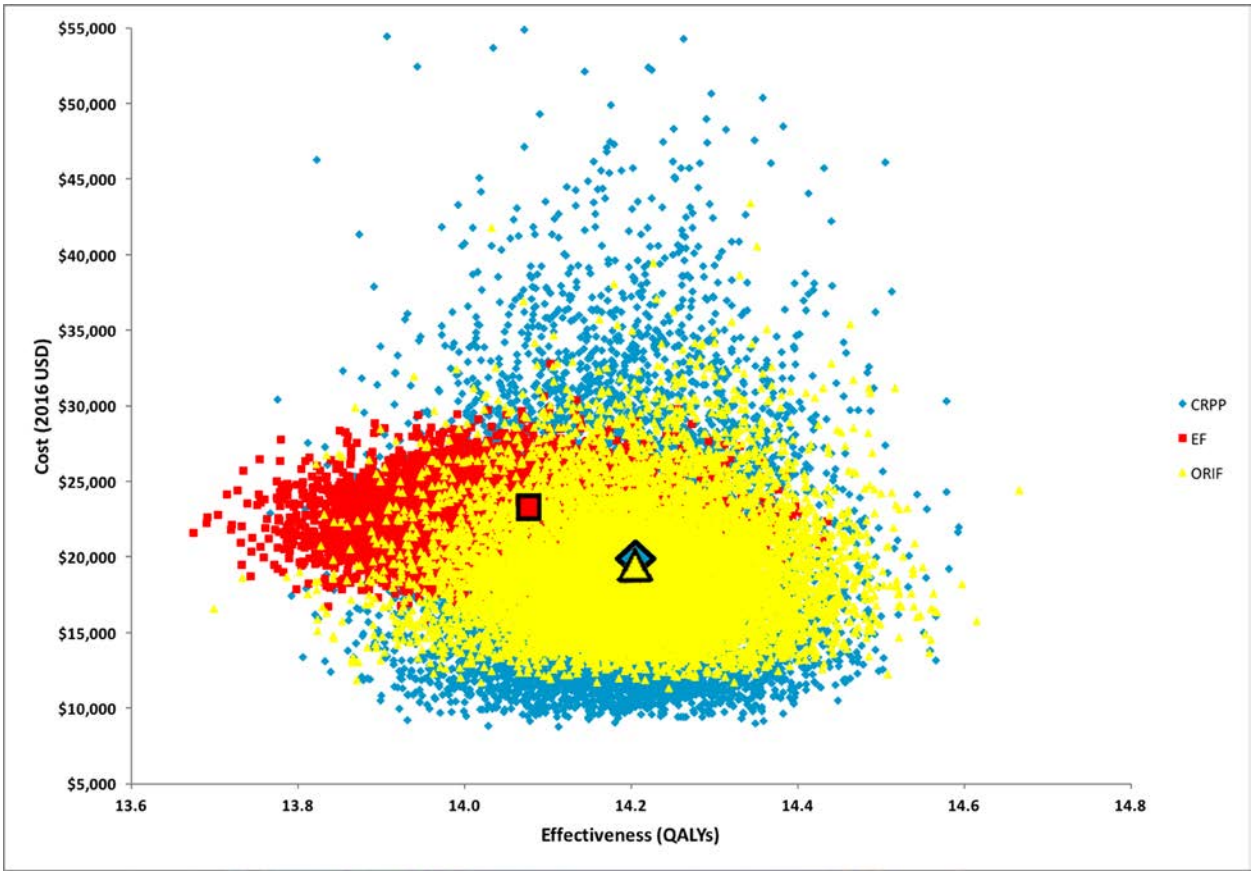

Fig. E-2: Probabilistic sensitivity analysis scatterplot illustrating the cost-effectiveness results of 10,000 iterative runs from the societal perspective that additionally incorporates uncertainty around the number of days out of work. The mean cost-effectiveness results are represented by the large diamond for closed reduction and percutaneous pinning (CRPP), by the square for external fixation (EF), and by the triangle for open reduction and internal fixation (ORIF). ORIF was, on average, less costly ($19,196 compared with $19,387) than CRPP with roughly the same effectiveness (14.2 QALYs).