An Original Study

Operative Versus Nonoperative Treatment of Jones Fractures: A Decision Analysis Model

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Abstract

Optimal management of metadiaphyseal fifth metatarsal fractures (Jones fractures) remains controversial. Decision analysis can optimize clinical decision-making based on available evidence and patient preferences.

We conducted a study to establish the determinants of decision-making and to determine the optimal treatment strategy for Jones fractures using a decision analysis model. Probabilities for potential outcomes of operative and nonoperative treatment of Jones fractures were determined from a review of the literature. Patient preferences for outcomes were obtained by questionnaire completed by 32 healthy adults with no history of foot fracture. Derived values were used in the model as a measure of utility. A decision tree was constructed, and fold-back and sensitivity analyses were performed to determine optimal treatment.

Nonoperative treatment was associated with a value of 7.74, and operative treatment with an intramedullary screw was associated with a value of 7.88 given the outcome probabilities and utilities studied, making operative treatment the optimal strategy. When parameters were varied, nonoperative treatment was favored when the likelihood of healing with nonoperative treatment rose above 82% and when the probability of healing after surgery fell below 92%.

In this decision analysis model, operative fixation is the preferred management strategy for Jones fractures.

The optimal management strategy for acute fractures of the metadiaphyseal fifth metatarsal (Jones fractures) is controversial. Patients can be successfully treated nonoperatively with non-weight-bearing and immobilization in a short leg cast[1-7] or operatively with placement of an intramedullary screw.[8-10] The primary advantage of nonoperative treatment is avoiding the risks and discomfort of surgery; disadvantages include the need for prolonged immobilization and protected weight-bearing as well as a decreased union rate.[8,9] Advantages of operative treatment include accelerated functional recovery and an improved union rate; disadvantages include exposure to the risks, inconvenience, and discomfort of surgery. Clear, definitive evidence for guiding treatment is not available in the orthopedic literature, and treatment strategies vary substantially according to surgeon and patient preference.

Expected-value decision analysis, a research tool that helps guide decision-making in situations of uncertainty, has been effectively applied to other areas of uncertainty in the orthopedic literature.[11-14] Borrowed from gaming theory, the technique involves creating a decision tree to define the clinical problem, determining outcome probabilities and utilities, performing a fold-back analysis to determine the optimal decision-making strategy, and performing a sensitivity analysis to model the effect of varying outcome probabilities and utilities on decision-making. Decision analysis may therefore allow the clinician and the patient to optimize decision-making based on best available evidence and patient preferences. It also helps determine the most important factors affecting management strategies and the decision-making process, which may not always be intuitive.

In the present study, we used expected-

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value decision analysis to determine the optimal management strategy, operative or nonoperative, for acute Jones fracture. We also explored factors with the most influence on the model and identified important questions for future research.

Materials and Methods

Institutional review board approval was obtained for this study. Analysis was performed with Treeage Pro statistical software (Treeage Software).

Outcome Probabilities

Outcome probabilities were determined by reviewing the literature for articles on Jones fractures. This body of literature was summarized in a comprehensive review by Dean and colleagues[15], who extracted data from 19 studies: 1 randomized controlled trial, 1 prospective case series, and 17 retrospective case series.[15] We used data from these studies to determine outcome probabilities (**Table**).

Outcome Utilities

Utilities represent patient preferences for various disease states. Outcome utility values were obtained from 32 adults (25 women, 7 men) with no history of foot injury. Mean age was 32.4 years (range, 20-69 years). The questionnaire presented scenarios for the different outcomes and asked patients to rate these outcomes on a scale ranging

Table. **Outcome Probabilities in Decision Analysis Derived From 19 Studies Summarized in Review by Dean and Colleagues[15]**

| Study | Year | Nonoperative | | | Operative | | | | Total Fractures Treated |
		Healed	Nonunion, Surgery, Healed	Nonunion, Surgery, Minor Complication	Healed	Minor Complication	Nonunion, Surgery, Healed	Nonunion, Surgery, Minor Complication	
Nagao et al[27]	2012	0	0	0	56	3	1	0	60
Thomas and Davis[28]	2011	0	6	1	0	0	0	0	7
Habbu et al[29]	2011	0	10	4	0	0	0	0	14
Hunt and Anderson[30]	2011	0	5	0	0	0	16	0	21
Torg et al[7]	1984	26	17	2	0	0	1	0	46
Mologne et al[21]	2005	14	4	0	12	7	0	0	37
Chuckpaiwong et al[31]	2008	14	3	0	11	4	0	0	32
Devries et al[32]	2011	0	0	0	50	1	2	0	53
Porter et al[10]	2005	0	7	0	17	0	0	0	24
Porter et al[20]	2009	0	0	0	17	3	0	0	20
Reese et al[33]	2004	0	1	0	14	0	0	0	15
Lombardi et al[34]	2004	0	0	0	7	3	0	0	10
Portland et al[35]	2003	0	0	0	15	0	0	0	15
Clapper et al[36]	1995	18	7	0	0	0	0	0	25
Josefsson et al[37]	1994	24	0	0	0	0	0	0	24
Mindrebo et al[38]	1993	0	0	0	9	0	0	0	9
Zogby and Baker[39]	1987	10	0	0	0	0	0	0	10
Dameron[40]	1975	15	5	0	0	0	0	0	20
Fernandez[41]	1999	4	4	0	0	0	0	0	8
Totals	—	125.00	69.00	7.00	208.00	21.00	20.00	0.00	450.00

from 0 (worst possible outcome) to 10 (best possible outcome). The Sports subscale of the Foot and Ankle Ability Measure (FAAM) 16 was used to quantify patient activity level.

Decision Tree and Fold-Back Analysis

A decision tree was constructed with 1 decision node, 4 chance nodes, and 7 terminal nodes (**Figure 1)**. The decision tree demonstrates 2 different strategies for managing a Jones fracture. The decision node divides the tree into 2 branches: initial operative or nonoperative treatment. Both branches are followed by various chance nodes, each terminating in a discrete clinical outcome. Per convention, utility data were placed to the right of the terminal nodes, and probability data were placed under the terminal nodes.

Fold-back analysis was performed to identify the optimal strategy. Fold-back analysis involves multiplying each outcome utility by its associated probability, thereby providing an "expected value" for each clinical endpoint. Then, the expected values for each endpoint can be summed for a given management strategy, and the ultimate expected values of the different strategies can be compared.

The management strategy associated with the highest expected value is optimal for the given outcome utilities and probabilities.

Sensitivity Analysis

One-way sensitivity analysis was performed to model the effect on decision-making of changing the values for utility for uncomplicated surgery, utility for healing with nonoperative treatment, utility for uncomplicated treatment of nonunion, likelihood of healing with nonoperative treatment, likelihood of healing with surgery, and likelihood of minor complication with surgery. These were the variables found to affect the decision-making strategy within their clinically plausible ranges.

Results

Outcome Probabilities and Utilities

Outcome probabilities and utilities are illustrated in Figure 1. By convention, probabilities appear below the corresponding branches of the decision tree, and utilities appear at the end of each branch. Mean (SD) FAAM Sports subscale score was 84.6 (27.4). This subscale is scored as a percentage
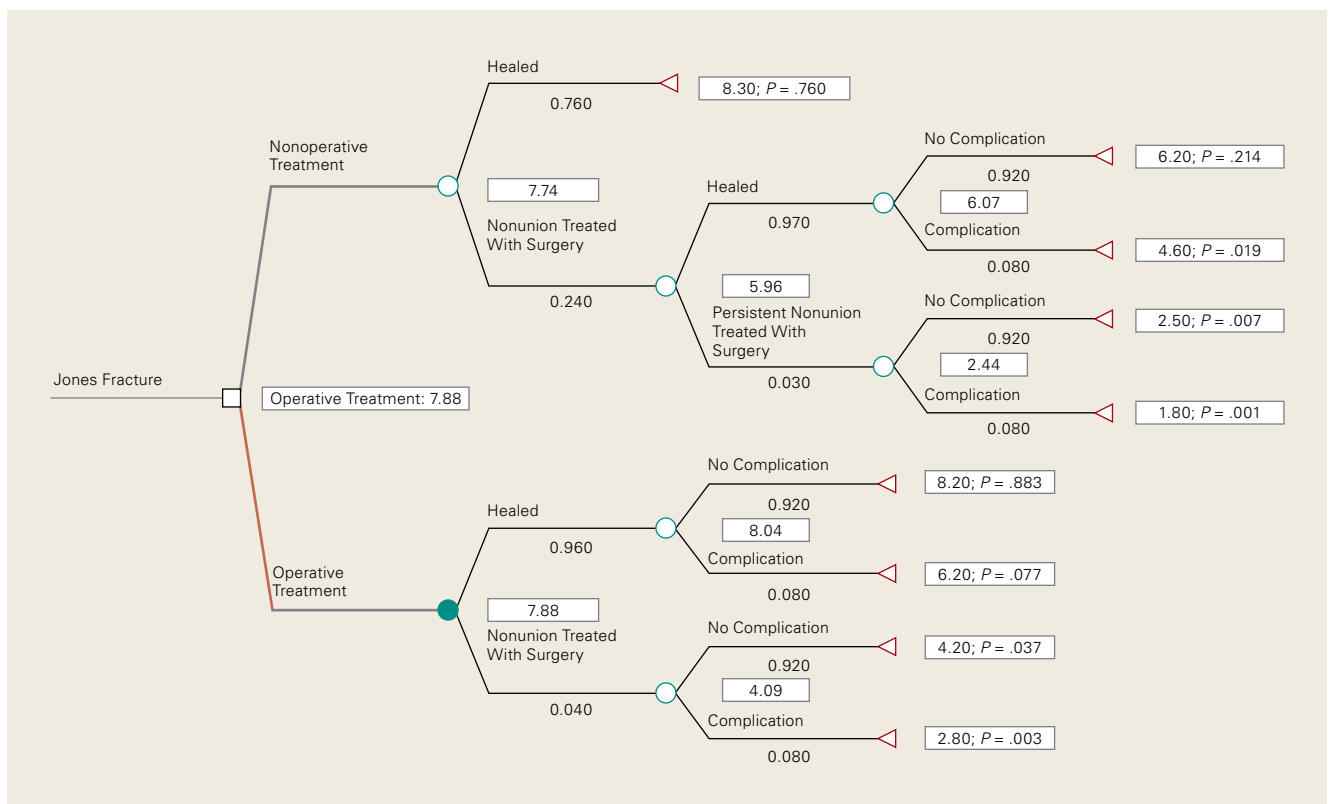

Figure 1. Completed decision tree includes outcome utilities, probabilities, and expected values of each treatment strategy.

from 0% to 100%, with higher scores indicating a higher level of physical function.

Decision Analysis

The expected value for nonoperative treatment was 7.74, and the expected value for intramedullary screw fixation was 7.88 (Figure 1). Therefore, operative treatment was identified as the optimal treatment strategy.

Sensitivity analyses revealed that the optimal decision making strategy was very sensitive to small changes in several variables. Nonoperative treatment becomes the preferred strategy when the utility value for uncomplicated surgery falls below 8.04 (**Figure 2**), when the utility for healing with nonoperative treatment rises above 8.49 (**Figure 3**), when the likelihood of healing with nonoperative treatment rises above 82% (**Figure 4**), or when the probability of healing after surgery falls

below 92% (**Figure 5**). Nonoperative treatment is also favored when the probability of minor complication with surgery is above 17% (**Figure 6**) and when utility for a successfully treated nonunion is higher than 6.9 (**Figure 7**).

Discussion

Optimal management of a metadiaphyseal fracture of the fifth metatarsal (Jones fracture) remains controversial. The decision between initial operative or nonoperative treatment lends itself to expected-value decision analysis because of well-defined treatment options and relatively discrete outcomes. The principal advantages of nonoperative treatment are that it allows the patient to avoid the risks and discomfort of surgery, and the principal advantages of operative treatment are that it maximizes the chance of fracture union and may accelerate functional recovery.
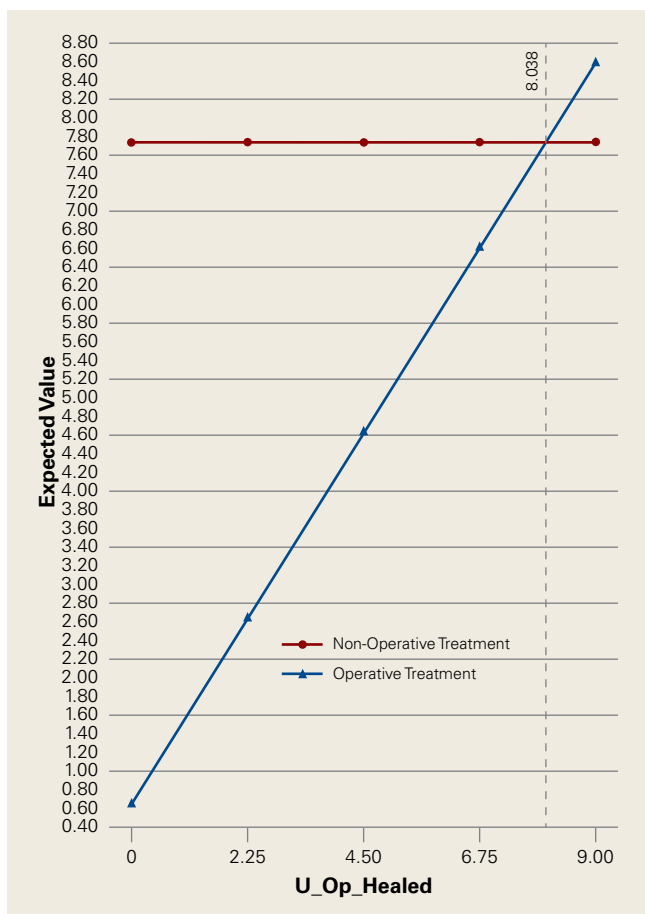

Figure 2. One-way sensitivity analysis for utility for uncomplicated healing with operative treatment. Utility of uncomplicated healing is varied on x-axis. Lines represent values for decision to manage operatively and nonoperatively. Below threshold value (utility for uncomplicated healing after operative treatment, 8.04), nonoperative treatment is favored.
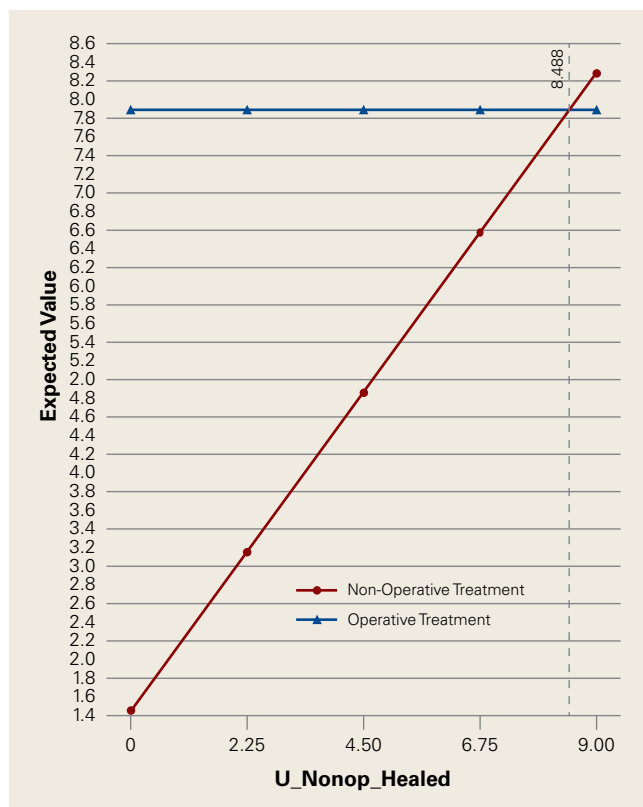

Figure 3. One-way sensitivity analysis for utility for uncomplicated healing with nonoperative treatment. Above threshold value (utility for uncomplicated healing after nonoperative treatment, 8.49), nonoperative treatment is favored.

Our decision analysis determined that operative fixation is the optimal decision path, given the outcome probabilities derived from the literature and the utilities obtained from surveys. This finding is in accordance with several expert opinions in foot and ankle fracture surgery.[17,18] However, the expected values of the operative and nonoperative treatment strategies differed by only 0.3 on a 10-point scale. Such similar expected values in our model are not surprising given the controversy surrounding clinical decision making in the treatment of these fractures.[19]

In addition, our analysis identified the important variables in the decision-making process. Patients averse to surgery, patients not averse to successful nonoperative treatment, and patients who view successful nonunion surgery after initial nonoperative treatment as a relatively positive outcome may be best treated nonoperatively. These findings emphasize the importance of patient preferences and shared decision-making. Higher rates of healing with nonoperative treatment, lower rates of healing with surgery, and higher complication rates with surgery also favor nonoperative management. It would therefore be valuable to identify risk factors for nonunion with nonoperative treatment and to identify the technical details of surgery that maximize rates of healing and minimize the risk of complications.

The limitations of decision analysis involve the methods by which probabilities and utilities are obtained. In general, the most accurate, stable, and robust estimates of outcome probabilities are derived from a meta-analytic synthesis of randomized clinical trials, the highest level of clinical evidence. In our model, data were extracted primarily from level IV studies; only 1 level III study[20] and 1 level II study[21] were available for analysis. Thus, as is
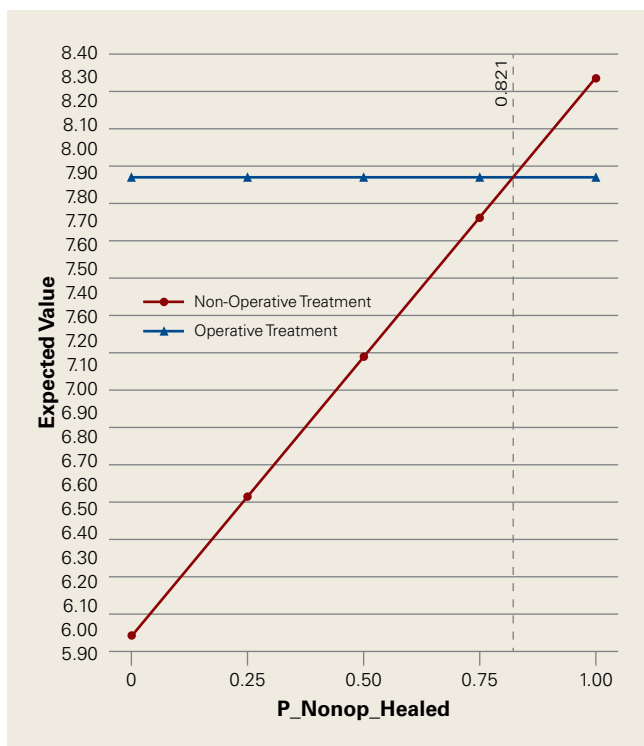

Figure 4. One-way sensitivity analysis for probability of healing with nonoperative treatment. Above threshold value (probability of healing after nonoperative treatment, 82%), nonoperative treatment is favored.
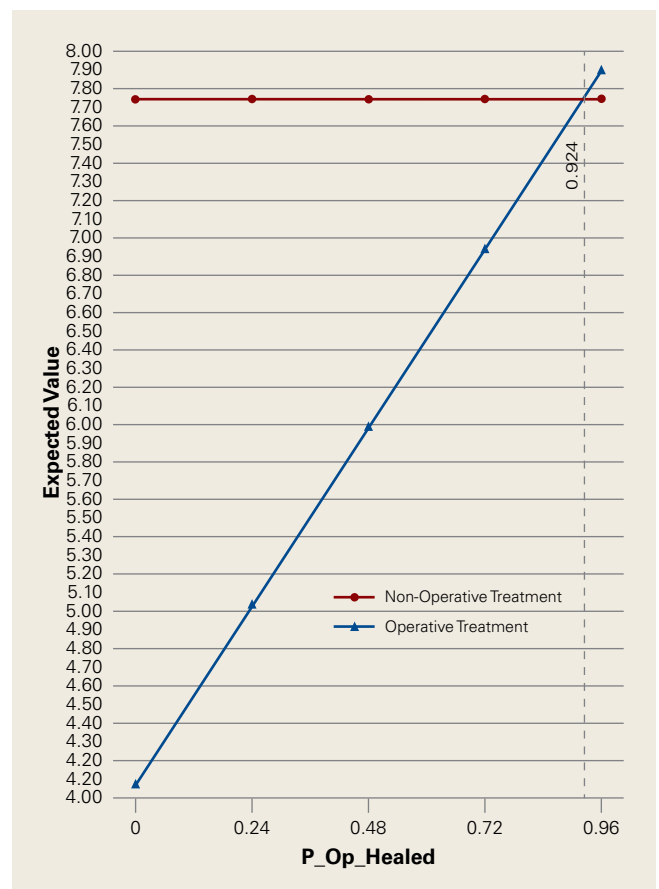

Figure 5. One-way sensitivity analysis for probability of healing with operative treatment. Below threshold value (probability of healing after operative treatment, 92%), nonoperative treatment is favored.

the case with many foot and ankle disorders[22], the information on treatment of Jones fractures is very limited in its level of clinical evidence.

Determination of outcome utility also has limitations. Utility is a subjective value that an individual places on a specific outcome. This can be very difficult to quantify. In general, the most robust estimates of patient-derived utilities are derived from complex qualitative methods, such as the standard reference gamble or time trade-offs, in which patients are asked to gamble or choose between health states usually referenced to death. In this study, we determined patient-derived utility values from a direct scaling method using a Likert scale because of the complexity of the standard reference gamble and the difficulty of referencing to death for metatarsal fracture. Although use of a direct scale to determine utility values is less rigorous than the standard reference gamble, this technique has been corroborated methodologi-

cally,[23] is advantageous in terms of feasibility and reliability,[24] and has been successfully used in other orthopedic decision analysis models.[12,25,26] In our estimation, generally active patients without a history of foot pathology constituted a sample of convenience but also were representative of individuals at risk for Jones fracture. Although specific scenarios were presented, the patients who completed the questionnaire may not have had deep insights into the subtleties and implications of the various disease states and treatments. Regardless of how outcome probabilities and utilities are determined, they are considered point estimates in decision analysis, and sensitivity analyses are therefore performed to assess how decision making changes over a range of values.

Conclusion

The results of this study may help optimize the process of deciding between operative and non-
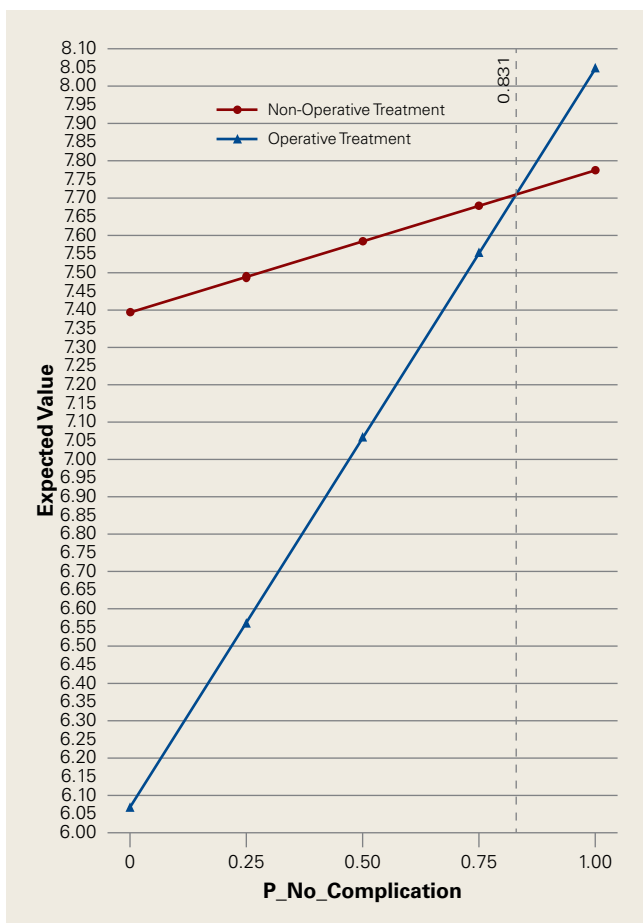

Figure 6. One-way sensitivity analysis for probability of minor complication with surgery. Above threshold value (probability of minor complication with surgery, 17%), nonoperative treatment is favored.
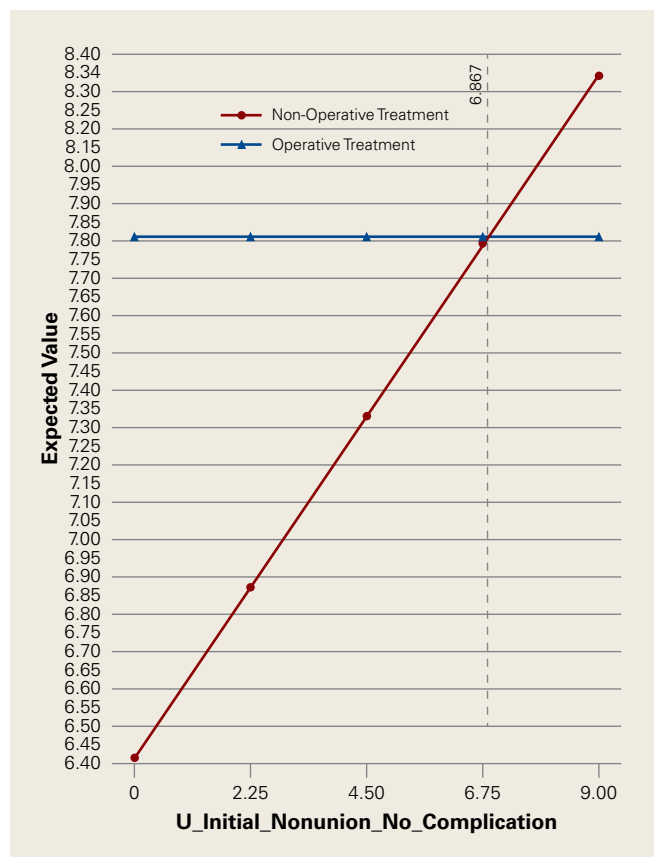

Figure 7. One-way sensitivity analysis for utility for successfully treated nonunion. Above threshold value (utility for successfully treated nonunion, 6.9), nonoperative treatment is favored.

operative treatment for Jones fracture. For a given patient, the optimal strategy depends not only on the probabilities of the various outcomes but also on personal preference. Thus, there may not be one right answer for all patients. Patients who value a higher chance of fracture healing with initial treatment or an earlier return to sports are best treated operatively, whereas patients who are risk-averse and place a high value on fracture healing without surgery should be managed nonoperatively. We therefore advocate a model of shared medical decision-making in which the physician and the patient are jointly involved, considering both outcome probabilities and patient preferences. Ongoing research efforts should focus on predictors of nonunion with nonoperative treatment.

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