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Total wrist arthroplasty and total wrist arthrodesis in rheumatoid arthritis: a decision analysis from the hand surgeons' perspective

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Abstract

Purpose—Treatment of severely destroyed rheumatoid wrists with total wrist arthroplasty (TWA) or total wrist fusion (TWF) relies on patient and surgeon preferences rather than rigorous prospective outcomes data. The purpose of this study is to develop a decision analytic model of TWA and TWF in rheumatoid arthritis using utility values obtained from a random sample of hand surgeons.

Methods—A utility survey using a time trade-off design was administered to 175 members of the American Society for Surgery of the Hand. Based on the results of the survey, the utility that surgeons assign to health states associated with TWA and TWF and their complications were calculated. By combining utility values with complication rates in the published literature, we developed a decision tree to calculate the expected quality adjusted life years (QALYs) for each procedure compared to living with a painful RA wrist.

Results—Based on surgeon preferences, living for 30 years with a painful, poorly functioning RA wrist (utility = 0.54) is associated with 16.2 QALYs. Treatment with TWA (utility = 0.85) is associated with 25.5 QALYs, a gain of 9.3 QALYs over non-operative management. TWF (utility = 0.82) is associated with 24.6 QALYs, a gain of 8.4 QALYs over non-operative management. TWA is associated with a small incremental increase in QALYs (0.9) compared to TWF.

Conclusions—Based on utility scores, hand surgeons feel that living with a painful, poorly functioning RA wrist for 30 years is worth approximately half as many years with a painless, well-functioning wrist. The outcomes for TWA and TWF are valued more than non-operative management. TWA is the preferred treatment since it is associated with the highest expected gain in QALYs. The minimal increase in utility for TWA over TWF suggests that surgeons do not view TWA as a superior to TWF.

Keywords

Total wrist arthroplasty; total wrist arthrodesis; rheumatoid arthritis; utility analysis; decision analysis

Introduction

For rheumatoid arthritis (RA) patients who present with destroyed, painful wrists, total wrist arthroplasty (TWA) and total wrist fusion (TWF) are appropriate options for reconstruction. A recent systematic review of TWA and TWF in rheumatoid arthritis (RA) (1) highlights the lack of prospective randomized trials to evaluate complications, functional outcomes and patient satisfaction for both procedures. In the absence of rigorous outcomes data, patient and surgeon preferences may be the most important factors in choosing between the two treatments. For example, a patient faced with the choice between TWA and TWF may focus on the desire to maintain wrist mobility in spite of the potentially higher complication rate associated with TWA. Conversely, a patient may prefer the procedure least likely to require additional revisional operations despite the loss of wrist mobility, making TWF more appealing.

Decision analysis is a method of assigning a level of desirability, or utility, to various health states. Perfect health is usually assumed to be the point of reference and by convention is assigned a utility value of 1.0, while death is assigned a utility value of 0(2). For example, given the theoretical choice between perfect health and blindness, a person may feel that living with blindness for 30 years is as valuable as living for 15 years with normal vision. In this case, blindness would be assigned a utility of 0.5 compared to perfect health, because the 30 years of life with blindness are considered to be as valuable as half as many years with normal vision. In a decision analysis, the utility for each health state is combined with the probability of the health state occurring as well as the time spent in that health state. For conditions with no clearly superior treatment option, including severe rheumatoid wrist disease, a decision analytic model allows calculation of the expected outcome of each available treatment. Decision analysis is becoming increasingly popular in the medical (3) and surgical (4, 5) literature. Numerous studies present decision analytic models of musculoskeletal conditions such as carpal tunnel syndrome (6, 7), total hip arthroplasty (8) and knee arthroplasty (9). Ultimately, data from decision analyses are combined with cost data to determine the cost-effectiveness of various management strategies.

The objective of this decision analytic model is to gain a better understanding of hand surgeons' preferences for management of the severely destroyed RA wrist. We developed a time trade-off (TTO) survey to evaluate the utility that hand surgeons assign to living with a painful, poorly-functioning RA wrist compared to treatment with TWA or TWF. Because hand surgeons wield a great deal of influence in guiding patients' selection of treatments, understanding the perspectives of surgeons is critical in evaluating the utilities surgeons give to various health states to arrive at a preferred treatment option. Preferences, in the form of utility values, can then be converted to quality adjusted life years (QALYs), which take into account both the quality of a health state and the duration of time within that state (2).

QALYs provide a single measure that captures both quantity and quality of life gains. In this case, QALYs for non-operative management (NOM), TWA and TWF are compared to determine the most favorable treatment option from the surgeon's perspective. Ultimately, QALY calculations for TWA and TWF can be applied in a cost-effectiveness or a cost-utility analysis to compare the procedures to one another and to other health interventions used to treat various conditions.

Methods

Survey Design

We developed a ten-item time trade-off (TTO) survey (Appendix 1) that was administered through the internet using the Zoomerang.com survey engine. To design the utility survey, we used background information derived from our prior systematic review of TWA and TWF (1). Data extracted through the extensive systematic literature search included complication rates for studies of TWA (10–27) and TWF (28–47) as well as the types of complications reported for each procedure. For this decision analysis, we divided the potential outcomes of each procedure into categories including major complication, intermediate complication, minor complication and no complication. Minor complications of TWF and TWA included delayed wound healing managed non-operatively and superficial wound infection treated with oral antibiotics. Examples of intermediate complications of TWF included symptomatic hardware requiring removal, superficial pin infection treated with pin removal, and postoperative carpal tunnel syndrome treated non-operatively. Examples of intermediate complications of TWA included hematoma requiring evacuation and functionally significant prosthesis imbalance managed non-operatively. Major complications of TWF included nonunion, pseudarthrosis, and deep infection requiring operative debridement. For TWA, examples of major complications included deep infection requiring operative management, dislocation of the prosthesis, and instability or loosening requiring operative intervention. We further subdivided major complications of TWA into those requiring revision arthroplasty and those requiring prosthesis removal and arthrodesis. We designed the utility survey to address each potential category of complications.

The survey was pilot tested across a group of medical students, surgical residents and attending physicians. At least three rounds of major revisions were performed with additional pilot testing after each revision. Two additional rounds of minor revisions were performed before the survey was deemed ready for administration. The TTO survey design required subjects to choose between a particular scenario related to living with a painful RA wrist and a scenario of living with a painless, well-functioning wrist. Assessment of utility based on TTO survey has been discussed in the utility literature and is considered to be an appropriate measurement tool (48–50). For example, the first scenario involved choosing between living for 30 years with a painful, poorly-functioning RA wrist and living for a shorter period of time (*X years*) with a painless, well-functioning wrist. The subject was always given the third option “it's too hard to choose.” The first scenario began with choosing between living 30 years with an RA wrist and living 30 years with a painless, well-functioning wrist. The obvious choice is living 30 years with a painless, well-functioning wrist. The time options then changed and the subject chose between living 30 years with an

RA wrist or living 15 years with a painless, well-functioning wrist. The number of years with an essentially normal wrist varied until the subject reached a point of indifference in which the choice between two scenarios became difficult. At the indifference point, the subject had decided the number of years of life with a normal wrist that he/she feels is equivalent to living 30 years with a painful RA wrist. In the example above, we will assume the subject decided that living for 20 years with a normal wrist is equivalent to 30 years with a painful RA wrist. The subject's utility for the scenario is calculated based on the point of indifference. In this example utility for the RA wrist would be 0.66 (20 years/30 years) compared to a normal wrist.

By convention, utility for death is zero and for perfect health is 1.0. We avoided using "perfect health" as a health state in our utility survey because our scenarios propose treatments to alleviate wrist pain and improve wrist function, but do not cure RA. Offering "perfect health" as a choice in the scenarios would reflect the respondent's feelings about RA as a systemic disease rather than focusing on opinions about RA wrist disease. For example, a patient may feel that living for 30 years with RA and a painful wrist is equivalent to living for 20 years with RA and a painless wrist (utility for having a painful RA wrist = 0.66), but might be willing to live for only 10 years in perfect health with no RA at all (utility for having RA and a painful RA wrist = 0.33). Therefore the optimal or "perfect" health state in our scenarios is RA with a "painless, well-functioning wrist."

Study Subjects

The study protocol was approved by the Institutional Review Board at the University of Michigan Medical Center. A random sample of 175 hand surgeons was chosen based upon 2007 membership in the American Society for Surgery of the Hand. Members were numbered in alphabetical order and a random number generator was used for selection. International members and emeritus members were excluded because we were interested in the preferences of hand surgeons currently in practice in the United States. Initial recruitment began with a mailed letter briefly explaining participation and was accompanied by a \$20 gift card to a national bookseller as a token gift for the surgeon's time. Two additional email reminders were sent and included the internet address for the survey engine. If an email address was not available, a reminder letter was sent via U.S. mail. Subjects were assigned a log-in number and individual responses to the survey remained anonymous. The utility survey was followed by a brief series of questions about the surgeon's training background, practice patterns, number of years in practice and an opportunity to include additional comments.

Data Analysis

Data were downloaded from the Zoomerang survey engine. For each scenario the utility score was calculated based on the point of indifference as described above. Survey data and demographic information were then entered into spreadsheet format and calculations were performed using the STATA software package (STATA 10, STATA Corp., College Station, TX). For utility scores, we calculated the mean value and 95% confidence intervals. We used summary statistics to evaluate demographic information.

A decision tree (Figure 1) was created using the TreeAge software program (TreeAge Pro Suite, Version 2007; TreeAge Software, Inc., Williamstown, Mass). By convention, the decision tree includes decision nodes (squares), chance nodes (circles), and terminal nodes (triangles). The initial branches of the tree show the three possible management options for the severe RA wrist: 1) living with pain and poor function, 2) TWA and 3) TWF. Subsequent branches for the surgical options show the potential outcomes, including no complication, minor complication, intermediate complication or major complication. Complication rates were derived from our systematic review as described above. For this analysis we assumed that a patient would have only one complication and that each complication has a definitive outcome. For example, delayed wound healing was assumed to go on to heal uneventfully with dressing changes and a superficial infection was assumed to resolve with antibiotic treatment. The lack of large scale published data on currently available wrist prostheses limits our ability to present complication rates in greater detail and prevents our assessment of the expected longevity of a given prosthesis. We therefore assumed that a successful prosthesis would last for the duration of the patient's life.

The TreeAge program is used in decision analyses to "roll back" the tree using the utilities and probabilities relevant to the study. The output from a decision tree is a calculation of the anticipated QALYs for each of the possible choices at the decision node. Additional values required for the calculations include the anticipated years of healthy life remaining and the duration of the health state under investigation. Because these values may vary, the TreeAge program allows a sensitivity analysis to vary the assumptions of the model and convey the associated changes in outcome. For example, complication rates are estimates. Varying the probability across the lower and higher complication rates reported in the literature allows us to evaluate how the calculated QALYs would change with higher or lower complication rates. Life span is also variable and the program allows us to change the potential remaining years of life to determine how a shortened lifespan may affect the QALYs a patient achieves with each possible option. Sensitivity analysis is therefore necessary to evaluate the robustness of a decision model and we chose to vary both remaining years of life and complication rates in this model.

Results

Survey Response

A total of 175 hand surgeons received a recruitment letter for the study. Seven surgeons contacted us to inform us of their retired status and were excluded. Incorrect mailing addresses resulted in 4 letters returned to us without forwarding addresses. After excluding retirees and those with whom we were unable to establish communication, our effective sample size was 164. Seventy three hand surgeons completed the entire survey making our overall response rate 73 out of 164, or 44.5%. This is slightly lower than the mean response rate for surveys mailed to physicians (51); however surgeons typically have a lower response rate than physicians in general, and rates for combined mail/internet surveys have not been studied in great detail. The survey was completed anonymously and therefore we do not have a way to further evaluate non-responders compared to responders.

Demographic Data

Demographic information is presented in Table 1. Of note, 90% of surgeons reported that at least 50% of their practice is dedicated to hand surgery; 43% of the surgeons have been in practice for 11 to 20 years and nearly 40% have been in practice for greater than 20 years. Survey results therefore represent the opinions of a very experienced group of hand surgeons. Surgeons were asked about their practice experience related to RA as well as TWA and TWF. Results are shown in Table 2. Of note, 84% of surgeons reported performing upper extremity operations for RA within an average month. Nearly 60% had performed a TWF for RA within the past year whereas less than 20% had performed a TWA for RA within the past year.

Utility Survey

Mean utility values that surgeons assigned to the ten scenarios are presented in Table 3 along with the 95% confidence intervals. To address non-operative management, the first scenario required the choice between living for 30 years with a painful, poorly-functioning RA wrist and living for fewer years with an essentially normal wrist. On average, surgeons preferred to live 16 years with a normal wrist instead of 30 years with a painful RA wrist. This corresponds to a utility score of 0.54 for living with a painful, poorly-functioning RA wrist ($16.1 \text{ years}/30 \text{ years} = 0.54$). The remaining scenario topics involving surgical management are also listed in Table 3. Mean values for the scenarios involving treatment with TWA or TWF ranged from 24.6 years (utility = 0.82) to 25.9 years (utility = 0.86) regardless of complications.

In reviewing the raw data for the first scenario, eleven surgeons preferred to live only 1 year with a normal wrist instead of 30 years with a painful RA wrist (utility = 0.03), essentially giving up 29 out of 30 years in exchange for a normal wrist. We were concerned that these respondents may have misread the survey. For the remaining 9 scenarios, only 5 or fewer surgeons chose this extreme trade-off, leading us to believe that either the surgeons had misread the first survey and better understood subsequent surveys, or they really did have an extremely low utility for living with a painful RA wrist. To evaluate the potential effect of these responses, we performed additional calculations of the mean utility value for each scenario by excluding all surveys in which respondents chose to live only 1 year (Table 3). With the exception of scenario 1 (choosing between a painful RA wrist and a normal wrist), all calculations show that even by excluding these responses, the recalculated values remain within the 95% confidence interval of the original calculation. The recalculated utility value for scenario 1 is only marginally outside of the 95% confidence interval of original calculation. The original calculations were therefore used for utility values in the decision tree.

The decision tree created using utility values from the survey is shown in Figure 2. QALY calculations were performed using the standard equation listed (Figure 3). All probabilities were derived from our prior systematic review and the time spent in the relevant health states is based on an estimate of the length of time it would take for the complication to resolve. The calculated QALYs for each branch of the tree are weighted based upon the probability of that event occurring. The probabilities for all of the possible outcomes of

TWA or TWF must add up to 1.0. For example, uncomplicated TWA is associated with 25.5 QALYs and has a probability of 70%. Therefore this branch contributes 17.85 QALYs ($25.5 \times 0.70 = 17.85$) to the expected outcome of TWA. The total expected QALYs for non-operative management (living with the painful wrist) is 16.20 QALYs for TWA is 25.50 QALYs, and for TWF is 24.60 QALYs. TWA is therefore the management strategy associated with the greatest expected gain in QALYs. The incremental gain for TWA compared to non-operative management is 9 QALYs and for TWA compared to TWF is 0.90 QALYs. This decision analysis model therefore indicates that both TWA and TWF are associated with a gain in expected QALYs compared to non-operative management. TWA is the preferred management strategy; however, the incremental difference between the expected gain in QALYs for TWA over TWF is quite small.

Sensitivity Analyses

Sensitivity analysis is necessary to evaluate whether changes in the assumptions of the model affect the final calculated outcome. For example, one assumption of this particular model is our estimate that patients undergoing TWA or TWF have 30 years of life remaining. In the United States, average lifespan is considered to be 77.8 years (52). Our prior systematic review indicates that the mean age of patients undergoing TWA is 55.8 years and for patients undergoing TWF is 57.2 years (1). Assuming a patient with RA has a normal lifespan, he/she would expect to live roughly 20 to 25 years after either procedure. A one-way sensitivity analysis allows us to look at the way in which a range of potential years of remaining life would affect the expected QALYs calculated in our model. We therefore specified a lifespan of 15 to 35 remaining years in the sensitivity analysis. Figure 4 shows a graphic representation of the effect of varying lifespan. The expected QALYs for TWA and TWF are still higher than for non-operative management, and even with a shortened lifespan, TWA remains more favorable than TWF. With a lifespan of only 15 years, TWA is associated with an incremental gain of 5 QALYs compared to non-operative management. With a lifespan of 35 years, TWA is associated with a gain of almost 10 QALYs compared to non-operative management. At any age, TWA is the more favorable treatment option; however the gain in expected QALYs diminishes with a shorter lifespan. Ultimately data from a decision analysis can be used in a cost utility analysis to determine cost per QALY. The cost per QALY for a 50 year-old undergoing TWA would be a much better value than the cost per QALY for an 80 year-old.

A second one-way sensitivity analysis was performed to evaluate the effect of changes in complication rates on the outcome of the decision tree. Complication rates for TWA vary widely in the published literature and established rates for the current prosthesis designs are not available. Given that TWA is the more favorable treatment option in our model, we performed a sensitivity analysis to determine whether increasing the major complication rate for TWA would eventually make it the less favorable surgical option. The baseline major complication rate for TWA used in our decision analysis was 24%. We therefore repeated the analysis using major complication rates of 50%, 80%, 90% and 92% for TWA (Table 4). Although this would seem to make TWA a less favorable option, there was minimal change in the expected QALYs for TWA. Stability of the results of the decision analysis in the

setting of drastic changes in the underlying assumptions indicates that our model is fairly robust.

Discussion

Decision analytic models have become a very useful tool for evaluating outcomes of medical interventions. Over the past several years, multiple publications have provided guidelines for performing and presenting these analyses (2, 49, 53–55). The result of a decision analysis is reported in terms of expected QALYs gained with an intervention. Calculating QALYs takes into account both the quality of a health state and the duration of time within that state, allowing a single measure to capture both quality gains and quantity gains (2). Gains in QALYs can then be compared across procedures to determine the relative benefit of one intervention over another. Cost per gain in QALY is the unit of measurement in cost utility analyses. Therefore the relative cost per QALY for interventions as different as liver transplantation and placement of a cochlear implant, for example, can be compared side by side. These cost comparisons can be used in establishing priorities for health care spending and can be used as a tool in influencing health care policy.

We chose to investigate management strategies for the RA wrist because of our desire to better understand why TWA has failed to gain widespread popularity. Our study participants are experienced hand surgeons from the ASSH and can provide the most qualified expert opinions on this topic. Our demographic data support this assumption in that all surgeons have been in practice for at least 5 years and approximately 90% report that more than half of their practice is dedicated to hand surgery. Our survey results demonstrate that the majority of our respondents have performed zero TWAs in the past year (77%), supporting our assessment that TWA is used relatively infrequently for the RA wrist. Surgeons performing TWA for RA reported between 1 and 5 cases per year. Given that 1% of the population suffers from RA (56) and 90% of these patients go on to develop wrist disease (57), we estimate that more patients would be candidates for TWA than actually undergo the procedure. Underutilization of potentially beneficial upper extremity operations has been demonstrated in prior studies (58, 59) and may be related to several factors such as lack of awareness on the part of patients and referring physicians, referring physician belief that the procedures are not beneficial, or in the case of TWA possible surgeon concern about the high complication and re-operation rates reported in the literature. The failure of TWA to achieve widespread use over the past few decades may also limit individual surgeon exposure to the procedure during their training period and may make them less likely to adopt the procedure in their own practices.

Utility values can be obtained through direct or indirect methods of measurement. For direct methods such as the visual analog scale (60), time trade-off (TTO) (61), and standard gamble (SG)(62), respondents assess the clinical health state and assign a value to it. Utility can then be directly calculated based on the respondent's preference for the health state. The health state is often theoretical and therefore the respondent does not necessarily have to be affected by the health state. Indirect methods for calculating utility include several available multi-attribute health status classifications such as the Health Utilities Index (HUI), and the EuroQoI (see Torrance, 1986 for review). The multi-attribute questionnaire is completed by

someone affected by the health state and a scoring formula is used to convert the responses into utility values based on comparison with responses from the general population.

The choice of which method to use to calculate utility depends mainly on the question under investigation. In a drug trial for example, indirect methods using multi-attribute health status questionnaires would allow assessment of a group of patients before and after treatment (63). For studies in which surgical interventions are compared, indirect utility measurement using a multi-attribute health status questionnaire could be administered to patients pre- and post-operatively; however achieving large enough numbers for meaningful analysis of a procedure such as TWA would be difficult. In addition, changes in technology such as prosthesis design would quickly make the results for prior models irrelevant. Direct assessment using SG or TTO survey allows each patient or survey respondent to explore multiple potential treatment options and express opinions and preferences for multiple options at the same time. Large joint arthroplasty (8, 9), management of scaphoid fractures (61), and composite tissue transplantation for facial defects (64) have all been evaluated with direct utility measurement. In evaluating results of one study or comparing results across multiple studies, the method used to measure utility should be clear and the potential for systematically higher or lower values with one method compared to another must be considered (65, 66).

In this study, we chose to use a TTO design because it allowed us to present a description of the surgical procedures and the anticipated complications. Respondents directly indicate the number of healthy years they feel are equivalent to a given number of years in a less desirable health state, which makes conversion to utility values quite straightforward. SG would similarly provide a means of presenting patients with theoretical health state scenarios, but the choice would compare a treatment that would result in a complete cure of the health state or certain death, with variable probabilities for the scenarios. The respondent chooses the probability of death that he/she is willing to accept. Studies of the SG technique suggest that the respondent makes a choice based on the desire to avoid death and therefore the results may be more reflective of risk aversion than preference for the health state (2). Evaluation of odds is also a challenging mental task. The TTO design may be easier for respondents with less experience with statistics to understand and we felt this design would be more useful in a survey that we hoped to eventually administer to patients.

Utility values were calculated for each of the ten scenarios. The first scenario addressed living with a painful rheumatoid wrist. The mean result of 16.1 years correlates with the surgeons' opinion that living 30 years with a painful RA wrist is equivalent to roughly half as many years with a normal wrist, a utility value of 0.54. In other words, surgeons, in general, are willing to trade nearly 14 years of life to avoid the health state of living with a painful wrist. Clearly survey respondents believe that a painful RA wrist severely compromises quality of life. For comparison, utility values for other conditions reported in the literature include 0.3 for blindness (62), 0.7 for liver transplantation (67), and 0.4 for paraplegia (68).

The scenarios associated with TWA (scenarios 2–6) cover a range of postoperative courses including no complication, minor complication, intermediate complication, and major

complication necessitating revision arthroplasty or salvage arthrodesis with an iliac crest bone grafting. Although surgeons show a slightly higher utility for uncomplicated TWA (0.85) compared to complicated TWA (0.82), the utility changes very little across the spectrum of complication severity. Scenarios for TWF (7–10) also cover a range of complications. Again utility does not seem to decrease across the spectrum of complication severity. The overall similar utility values for TWA compared to TWF as well as the minimal change in utility across the spectrum of complications suggests the difference in surgeon-rated utility for TWA compared to TWF is quite small.

Our findings therefore raise a few possible explanations. First, based on the similar utility for TWA compared to TWF, surgeons may feel that TWA, as is currently available, offers no substantial functional benefit compared to TWF. This might also explain the relative infrequency with which TWA is performed by the surgeons in our sample. Second, as our systematic review highlighted, the complication, revision and re-operation rates reported in the literature for TWA are higher than for TWF. Surgeons may be reluctant to choose TWA due to concerns about the risks associated with the procedure and the uncertain long term durability of available prostheses. Third, rheumatoid wrist disease is a chronic condition with severe morbidity but no direct effect on mortality. Surgical intervention may improve the RA patient's quality of life by relieving pain and increasing functional abilities, but TWA and TWF do not offer a survival benefit. The nature of the TTO survey asks the respondents to trade life years in exchange for treatment of a non life-threatening condition. Even if surgeons believe that TWA and TWF are effective and worthwhile procedures, they may not be willing to give up valuable years of life and therefore the utility scores may not truly reflect surgeons' opinions about the individual procedures. This possibility certainly could explain our utility survey results but does not explain why surgeons have not widely adopted TWA.

Based on our decision analytic model, TWA is associated with a larger expected gain in QALYs than TWF. This result held up through our sensitivity analyses in which we varied complication rates and expected lifespan. Compared to living with a painful RA wrist, TWA is associated with a gain of approximately 10 QALYs. Compared to TWF, TWA is associated with an expected gain of 0.9 QALYs. Historically, cost-utility analyses in which the intervention is associated with a cost of \$50,000 per QALY have been considered to be cost-effective. More recent studies indicate that the lower threshold of cost-effectiveness is substantially higher than \$50,000 (69). In the case of TWA, a gain of 10 QALYs compared to non-operative management would mean that even at a cost of \$500,000 for TWA would be considered cost-effective. For TWF compared to non-operative management, the incremental gain of 8.4 QALYs would be considered cost-effective even at a cost of \$420,000. Clearly both TWA and TWF are likely to be very cost-effective treatments for the RA wrist.

TWA has been historically associated with high complication and revision rates; however there is very little published data on currently available total wrist prostheses. In our prior systematic review we found that published outcomes for TWA show no substantial benefit compared to TWF in terms of patient satisfaction and achievement of a functional arc of motion. Results were limited by the fact that the studies were mainly small retrospective

case series with inconsistent reporting of outcomes. In the absence of rigorous evidence, decision making must rely on the opinions and preferences of patients and hand surgeons. This decision analytic model has allowed us to better understand surgeon preference for TWA and TWF compared to non-operative management. We found a strong preference for operative management of the RA wrist over non-operative management. However surgeons responding to our survey showed only minimal preference for TWA over TWF and perform relatively few total wrist arthroplasties for RA.

Efforts to improve large joint arthroplasty have led to very high success rates and patient satisfaction with total hip and total knee prostheses. We feel that efforts to improve treatment options for severe wrist disease should parallel the efforts put forth in the development of large joint prostheses. Prospective outcome data on the currently available total wrist prostheses will provide surgeons and patients with updated complication and revision rates as well as data on the functional outcome and longevity associated with each prosthesis design. Until such data are available, decision making will continue to rely on the opinions and preferences of patients and hand surgeons. Efforts to model the potential clinical scenarios, including this decision analysis, provide insight into the opinions and priorities that go into decision making under uncertain conditions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Outline of decision tree for TWA, TWF, and non-operative management. Square indicates decision node, circle indicates chance node, and triangle indicates terminal node.

Figure 2.

Decision tree with calculations. Probabilities are shown for each category of possible complications. Expected QALYs for each management strategy are shown on the left.

$$(\text{Duration of Health State}) \times (\text{Utility Health State}) + (\text{Healthy Years} - \text{Complication Time}) \times (\text{Utility Healthy Years}) = \text{QALYs}$$

Sample Calculation using Scenario 3: TWF with Minor Complication

Health State = Complication (Superficial wound infection)

Duration of Health State = 2 weeks (0.038 years)

Utility Complication (from survey scenario 3) = 0.87

Healthy Years = 30

Utility Remaining Healthy Years = utility patient will have after complication resolves*

*Same as utility for uncomplicated TWF (from survey scenario 2 = 0.85)

$$(0.038 \text{ years}) \times (0.87) + (30 \text{ years} - 0.038 \text{ years}) \times (0.85) = 25.5 \text{ QALYs}$$

Figure 3.

Equation used for calculation of QALYs.

Figure 4. Sensitivity analysis evaluating change in expected QALYS with range of 15 to 35 healthy remaining years of life.

Table 1

Demographic profile of surgeons responding to survey

Demographic Information (N= 73)			
Gender	M = 68 (93%) F = 5 (7%)		
Years in Practice	Mean 18.8	SD 8.4	Range 5 to >30
Percent Hand Surgery	Mean 84.1%	SD 23.7%	Range 5 – 100%
Practice Setting			
Academic	N = 20 (27%)		
Private	N = 38 (52%)		
Combination	N = 15 (21%)		
Training Background	Orthopedic Surgery = 61 (84%) Plastic Surgery = 9 (12%) General Surgery = 3 (4%)		

Table 2

Surgeon Reporting of TWA and TWF Performed in the Past 1 Year

Number of Operations	Number of Surgeons Reporting				
	* Operations for RA	TWFs for all conditions	TWFs for RA	TWAs for all conditions	TWAs for RA
0	12 (16%)	18 (25%)	30 (41%)	56 (77%)	59 (81%)
1 to 5	54 (74%)	46 (63%)	40 (55%)	17 (23%)	14 (19%)
6 to 10	5 (7%)	9 (12%)	3 (4%)	0	0
11 to 15	2 (3%)	0	0	0	0
> 15	0	0	0	0	0
Total number of operations performed within the past year by all surgeons responding to survey		205 TWFs	94 TWFs for RA	34 TWAs	33 TWAs for RA

* Note: Operations for RA is the number of hand procedures performed in an average month, remainder of categories indicate number of procedures performed per year

Table 3

Utility Survey Results

	Scenario	* Mean Number of Healthy Years	Mean Utility (95% CI)	** Mean Utility
1	Non-operative treatment	16.1	0.54 (0.46 – 0.61)	0.62
2	TWF no complication	24.6	0.82 (0.75 – 0.88)	0.85
3	TWF minor complication	25.4	0.85 (0.79 – 0.90)	0.87
4	TWF intermediate complication	25.9	0.86 (0.81 – 0.92)	0.90
5	TWF major complication	24.6	0.82 (0.76 – 0.88)	0.85
6	TWA no complication	25.5	0.85 (0.79 – 0.91)	0.87
7	TWA minor complication	25.4	0.85 (0.78 – 0.91)	0.91
8	TWA intermediate complication	25.9	0.86 (0.80 – 0.92)	0.87
9	TWA major complication: revision arthroplasty	24.7	0.82 (0.76 – 0.88)	0.86
10	TWA major complication: arthrodesis	24.5	0.82 (0.76 – 0.88)	0.85

* Mean number of healthy years the respondent felt was equivalent to living 30 years with RA treated using the option listed in the scenario

** Mean utility value calculated excluding responses in which the surgeon was willing to trade 29 of 30 remaining years

Table 4

Sensitivity Analysis for TWA

* Total Major Complication Rate TWA	Expected QALYs TWA
**24.2%	25.5
50%	25.5
80%	25.5
90%	25.5
92%	25.49

* Total Major Complication Rate includes the combined rates for both TWA requiring replacement of the wrist prosthesis and removal of the prosthesis with salvage arthrodesis

** 24.2% is the mean Total Major Complication Rate reported in the literature and used in our other calculations