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Cost-effectiveness Analysis of Core Decompression

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Abstract: Core decompression is widely used to treat the early stages of osteonecrosis of the hip. The purpose of this analysis is to assist orthopedic surgeons in judging whether currently available data support the use of core decompression as cost-effective. A decision model was created for the treatment of osteonecrosis of the femoral head. Literature review was used to identify possible outcomes and their probability after initial treatment with either observation or core decompression. This model demonstrates core decompression must delay the need for total hip arthroplasty for a minimum of 5 years to maintain an incremental cost-effectiveness ratio lower than \$50 000 per quality-adjusted life year gained. Treatment options with ratios higher than \$50 000 per quality-adjusted life year are generally considered to have limited cost-effectiveness. This study demonstrates that core decompression has the potential to be a highly cost-effective alternative if it is leads to a delay in the need for total hip arthroplasty of 5 years or longer. **Key words:** avascular necrosis, osteonecrosis, core decompression, cost-effectiveness.

Osteonecrosis of the hip is a disease of impaired osseous blood supply that commonly affects patients in the third, fourth, or fifth decade of life. It can eventually lead to collapse of the femoral head and painful arthritis of the hip joint. End-stage osteonecrosis is treated with total hip arthroplasty (THA) and accounts for 5% to 12% of such procedures. Despite the clinical success of primary hip arthroplasty in this population, significant concerns persist about the long-term outcomes of younger patients undergoing prosthetic joint arthroplasty. These concerns underlie the widespread use of core decompression in the early stages of osteonecrosis, with the goal of delaying or preventing the need for hip arthroplasty [1,2].

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The indications for core decompression have not been definitively established. There is significant variation in the published data regarding the efficacy of core decompression [3-11]. In addition, there is uncertainty regarding the optimal surgical technique for performing this procedure. These discrepancies have prevented the development of a clear consensus on the clinical use of this procedure. The goal of core decompression is to relieve pain and delay the need for THA. In this era of limited health-care resources, it is essential to determine if surgical procedures are cost-effective. The purpose of this analysis is to assist orthopedic surgeons in judging whether currently available data support the cost-effectiveness of core decompression in the treatment of early-stage osteonecrosis of the hip.

Materials and Methods

General Framing and Design

This cost-effectiveness analysis follows the methodological guidelines of the Panel on Cost-effectiveness in Health and Medicine convened by the US Public Health Service in 1993 [12]. The panel outlined an explicit set of recommendations in a reference case analysis. These reference case guidelines established a common set of standards to improve the comparability of cost-effectiveness analyses. Issues addressed in the reference case analysis include standard practices for framing and perspective of the study, identification of outcomes, estimation of costs, and testing of uncertainty [12]. This study was constructed adhering to these standards.

Consistent with the reference case guidelines, this analysis compares the cost-effectiveness of core decompression to the commonly accepted treatment alternative of observation in the early stages of osteonecrosis. This analysis assumes a target patient population seeking treatment of femoral osteonecrosis at the age of 40 years. The time horizon of this analysis encompasses the remaining life expectancy for this target population.

The cost-effectiveness ratios for observation and core decompression were analyzed from the societal perspective. The boundary of the analysis is limited to the costs and health effects directly impacting the target population. Estimates of costs, effectiveness, and the probability of various outcomes were obtained from literature review.

Literature Review

Literature review was used to construct the event pathways following observation and core decompression. A literature search identified 269 articles between 1978 and 2004 using the keywords *osteonecrosis*, *decompression*, *hip*, and *outcome*. Seventy-eight articles were identified as relevant to the treatment of osteonecrosis with either core decompression or observation. Fifteen publications were review articles and excluded from further analysis. The remaining articles were assessed on their quality. We excluded articles with fewer than 50 subjects. Additional criteria used to select articles included adequate reporting of magnetic resonance imaging staging and standardized surgical technique. A total of 11 studies were identified and selected for abstraction using these criteria. The abstracted data are included as Appendix A and list the study design, number of subjects, results, and complications reported in each reference.

Decision Model

Decision tree software (TreeAge Pro; TreeAge Software Inc, Williamston, Mass) was used to create a model for the treatment of femoral head osteonecrosis [13-19]. A simplified schematic of the decision tree is shown in Fig. 1. The full decision model is included as Appendix B. The model begins with the decision for either observation or core decompression. Literature review was used to identify possible outcomes and their probability after each of these treatment alternatives. These event pathways were incorporated as branches in the decision tree. This model assumed a target population of patients seeking treatment of osteonecrosis at the age of 40 years. This age is consistent with the typical age at which core decompression is performed for osteonecrosis of the hip [1]. The time horizon of the model follows events through the remaining life expectancy of 39 years for this age group [20]. The event pathway for observation follows the clinical course of patients with early osteonecrosis and assumes that they become symptomatic and require THA after a 2-year period. This period is consistent with the natural history of osteonecrosis [1,21,22].

The event pathways following core decompression were constructed following literature review. There has been a wide range of results reported on the efficacy of core decompression [3-11]. The clinical results abstracted from the literature review are summarized in Appendix A. A reference case was created and assumed a period of 10 years before the need for primary hip arthroplasty after

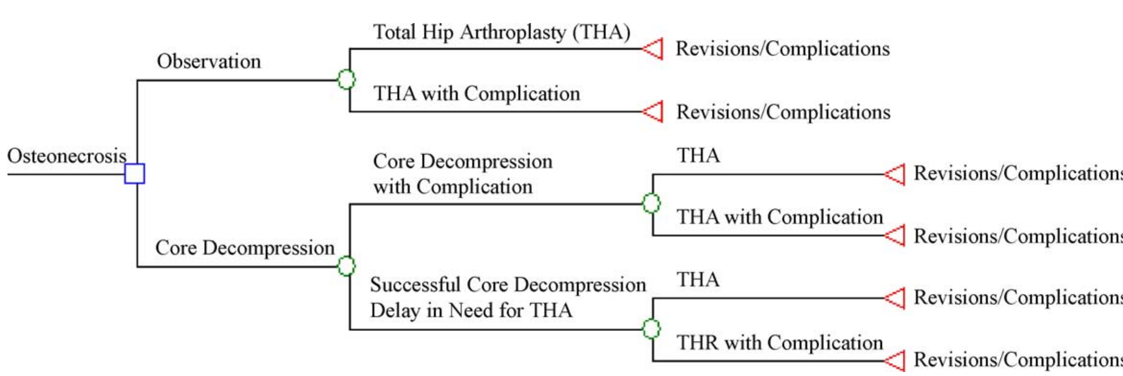


Fig. 1. Simplified schematic of decision model for the treatment of femoral head osteonecrosis.

Table 1. Complication Rates Used in Decision Model After THA

Complication	Probability (%)
Complication rate primary THA	4
Infection	1
Dislocation	2.5
Mortality	0.5
Complication rate revision THA	10
Complication rate second or third revision THA	15

core decompression compared with 2 years with observation. This assumption is consistent with the more favorable reports of the results of core decompression. The efficacy of core decompression in delaying hip arthroplasty for this duration has not been definitively established in the published literature. Given this uncertainty, the effects on the cost-effectiveness of core decompression of both shorter and longer assumptions for its efficacy are examined in the sensitivity analysis. The primary complication included in the model following core decompression is subtrochanteric hip fracture requiring operative intervention. This complication has been infrequently reported, but rates as high as 5% have been published [3-11]. An intermediate value of 2% was selected for the reference case, and sensitivity analysis was used to examine the effect of rates in the range of 0% to 5%.

Subsequent events after observation and core decompression are modeled to include the potential need for hip arthroplasty and revisions over the lifetimes of the target population. Complications after hip arthroplasty include dislocation, infection, and death [23]. The decision model incorporates the need for subsequent hip revision surgery and the possible complications that can arise. The incidence of complications is assumed to increase with subsequent revision procedures, whereas the durability of revision arthroplasty is assumed to decrease relative to primary arthroplasty [24,26,27]. The probabilities of infection, dislocation, and mortality used in this model are shown in Table 1. The rates of these complications were selected to fall in the midrange of estimates reported in the literature. Most studies have reported rates of infection leading to implant failure near the value of 1% used in the reference case of this study [25-28]. Mortality and dislocation rates have not been as definitively established. The reference case of 0.5% for mortality is consistent with the low rates generally reported [29]. The dislocation rate of 2.5% used in the reference case is consistent with reports of large database studies [23,27]. Sensitivity analysis was used to address the uncertainty of these assumptions for complication rates by examining the effect of higher and lower rates on the results.

Effectiveness

This study is a special case of cost-effectiveness analysis termed cost-utility analysis. Cost-utility analyses are differentiated by the fact that effectiveness is measured in units that incorporate a subjective measure of utility such as quality-adjusted life years (QALYs). The treatment of osteonecrosis has limited effect on survival but does result in significant changes in the quality of life of patients. The use of QALYs to measure effectiveness allows the survival of patients in different health states to be corrected for health-related quality of life using a utility factor.

Utility factors were assigned to all health states in the model to adjust survival for quality of life. The reference case guidelines define utility along a continuum with a factor of 1.0 representing perfect health and a factor of 0.0 representing death [12]. Specific utility values for each health state in this study were assigned following a literature review. Table 2 lists the health states included in the decision model along with their corresponding utility values. Large-scale studies have used questionnaires to establish utility values for a variety of health states. Arthritis has consistently been shown to have a utility value near 0.7 [30-33]. Knee and hip arthroplasties have been shown to increase quality of life weightings close to normal values. Based on these studies, this analysis uses a utility value of 0.9 for successful hip arthroplasty. Revision arthroplasty is given a lower utility value to reflect the diminished clinical results compared with primary arthroplasty. The utility values used for resection arthroplasty and surgical complications were also identified in literature review.

The period after successful core decompression was assigned a utility similar to that of successful arthroplasty. This reflects the assumption that successful core decompression results in a well-functioning hip but does not completely restore

Table 2. Utility Values for Health States Occurring in Decision Model

Health state	Utility value
Primary THA	0.9
Treatment of dislocation	0.5
Treatment of infection	0.5
Surgery and postoperative recovery	0.5
Death	0.0
Successful core decompression	0.9
Revision THA	0.85
Resection hip arthroplasty	0.6

normal utility. The ability of core decompression to control symptoms and maintain a high level of function has not been definitively documented in the published literature. To address this uncertainty, sensitivity analysis was used to examine the impact of both higher and lower utility values after core decompression on its cost-effectiveness.

Costs

Gross-costing methodology was used to estimate the direct lifetime treatment costs after both observation and core decompression [12]. This methodology relies on global Medicare charge and reimbursement data to approximate the direct costs for various procedures. Indirect costs such as lost productivity were not included in this analysis. The surgical interventions occurring in the decision model were assigned their appropriate *International Classification of Diseases, Ninth Revision*; diagnosis related groups (DRGs); and *Current Procedural Terminology* (*CPT*) codes. Gross cost estimates were then determined for short-term care hospitalizations and physician services based on charge and reimbursement data for these codes. The cost estimates are shown in Table 3.

Gross cost estimates for short-term care hospitalizations were determined from mean hospital costs for the DRG associated with each intervention. Mean hospital costs were based on data from the Centers for Medicare and Medicaid Services reported for 1998 [34]. These costs are derived by applying Medicare cost-to-charge ratios to the data from the MedPAR data source [34]. The MedPAR data source is released annually by Medicare and provides cost estimates for each DRG. This study used the MedPAR data for 1998 pertaining to all US hospitals [34,35].

The gross costs for physician services were determined from mean Medicare reimbursement for the *CPT* code associated with each surgical intervention.

Table 3. **Costs for DRG and *CPT* Codes Occurring in Decision Model Using 1998 Medicare Data**

Procedure	DRG (cost [$])	*CPT* (cost [$])
Core decompression	210 (8086)	27071 (825)
Primary THA	209 (9183)	27130 (1826)
Revision THA	209 (9183)	27134 (2572)
Resection arthroplasty	210 (8086)	27091 (1754)
Reduction of dislocated hip prosthesis	210 (8086)	27266 (483)
Operative treatment of infected hip prosthesis	210 (8086)	27030 (1021)
Open reduction and internal fixation of hip fracture	210 (8086)	27244 (1362)

The mean reimbursement reported by the Centers for Medicare and Medicaid Services in 1998 for the Los Angeles, Calif, carrier was used. This global reimbursement includes preoperative care, surgical fees, and 90 days of postoperative care [36].

Discounting

Cost-effectiveness analysis requires that all future costs and health consequences be discounted and stated in their present-day values. Discounting is performed to correct for the fact that costs that are deferred to the future are preferable to immediate expenditures. Costs and health effects were discounted in the reference case at a constant rate of 3% annually. Sensitivity analyses were conducted with discount rates of 0% and 5% [12,13].

Sensitivity Analysis

Sensitivity analysis was conducted to test the uncertainty of the reference case results. Cost-effectiveness analysis combines information from several data sources to generate estimates of the probability of different outcomes and assign values to their utility and costs. Uncertainty about the true values of these underlying parameters results in uncertainty about the cost-effectiveness ratios generated in the reference case. Sensitivity analysis is used to determine the impact of varying the assumed values for key variables on the conclusions generated by the cost-effectiveness analysis.

Initially, cost-effectiveness ratios were calculated using the reference case assumptions for both observation and core decompression. Sensitivity analysis was then performed using different assumptions for the values of the underlying variables [12]. Several key variables were selected for sensitivity analysis. These variables included the delay in hip arthroplasty resulting from core decompression, the functional utility after successful core decompression, the incidence of complications after core decompression, and the incidence of complications after both primary and revision hip arthroplasty.

Results

Reference Case Results

A reference case was created that assumed that core decompression delays the need for THA for 10 years. Given the uncertainty of this assumption, the effects on the cost-effectiveness of core decompression of both shorter and longer assumptions for its efficacy are examined in the sensitivity analysis.

In the reference case, the pathway of core decompression is assumed to delay hip arthroplasty for 10 years and resulted in 20.20 QALYs, whereas observation resulted in 19.75 QALYs. This represents an incremental gain of 0.45 QALYs when core decompression was chosen over observation. Core decompression generated total expected lifetime treatment costs of $27 498. This results in an incremental increase in cost of $4298 when compared with the lifetime treatment costs of $23 200 for observation followed by arthroplasty. This led to an incremental cost-effectiveness ratio of $9551 for each QALY gained when core decompression was chosen over observation.

Sensitivity Analysis

Effect of Changing the Assumed Length of the Delay in the Need for THA After Core Decompression. The reference case assumes that core decompression delays hip arthroplasty for 10 years as compared with 2 years with observation in the early stages of osteonecrosis. Core decompression has not been definitively demonstrated to result in delays of this length. There are conflicting reports in the literature, with some authors showing delays of this length and others reporting results below this threshold [1,2].

Sensitivity analysis was used to evaluate the effects of varying the underlying assumption for the success of core decompression on its cost-effectiveness ratio (Fig. 2). The cost-effectiveness of core decompression decreases as its assumed ability to delay hip arthroplasty decreases. The cost-effectiveness ratio rises to more than $25 000 per life year as the period of delay falls below 7 years. The $50 000 cost per life year gained threshold is passed as this period falls below 5 years.

Effect of Function After Core Decompression. The reference case assumes that successful core decompression prevents painful symptoms during the period it is delaying the need for primary arthroplasty. This control of pain is reflected in the high utility value of 0.9 assigned to patients during this waiting period.

Sensitivity analysis was conducted to model clinical situations in which core decompression does not perform well in mitigating the functional limitations caused by advancing osteonecrosis. The cost-effectiveness ratio of core decompression rises to more than $50 000 per QALY gained when the utility during the period after the procedure and before conversion to THA is assumed to be lower than 0.86 (Fig. 3).

Effect of Complication Rate After Core Decompression. Subtrochanteric hip fractures complicating core decompression have been reported infrequently, although some studies have shown rates as high as 5%. Sensitivity analysis demonstrated that the cost-effectiveness ratio rose or fell only slightly over the range of values from 0% to 5%. Even at an assumed fracture rate of 5%, the cost-effectiveness ratio of core decompression remained lower than $12 000 per QALY.

Effect of Complication Rates After Arthroplasty. The rates of complications after THA have been reported by several authors [23-29]. The assumed durability of hip arthroplasty and incidence of complications including death, dislocation, and infection were selected to be in the midrange of accepted values. Sensitivity analysis was used to examine the impact of using high- and low-range values for these variables. As the assumed complication rates after hip arthroplasty decrease, core decompression becomes a less cost-effective treatment

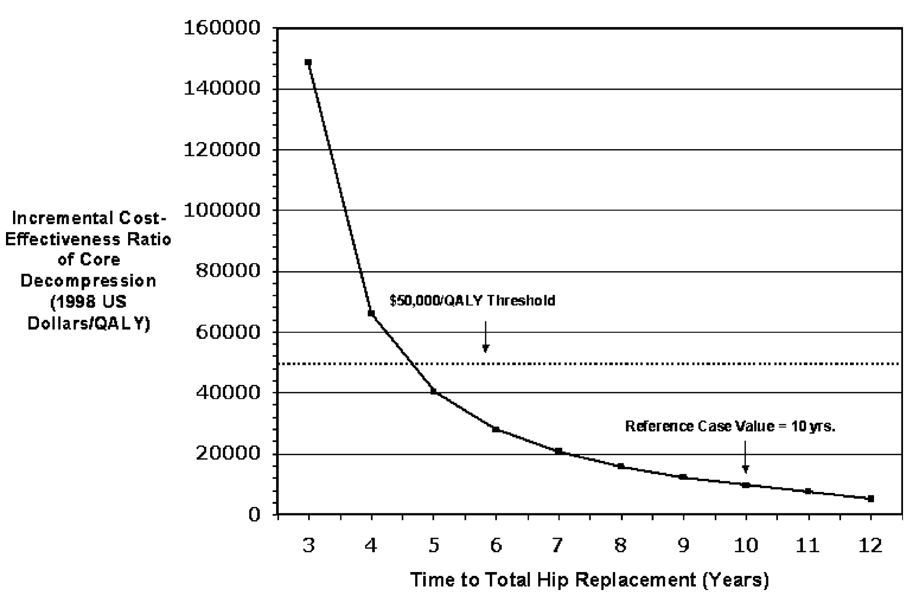


Fig. 2. Sensitivity analysis examining relationship between length of delay to primary hip arthroplasty and the incremental cost-effectiveness ratio of core decompression.

option. This occurs because some of the cost-effectiveness gains from core decompression result from the delay or avoidance of the costs and negative health impacts that result from these complications. However, these effects were not large and did not alter the conclusions of this study. Even under conditions in which the complication rates of THA are assumed to be negligible, core decompression remained highly cost-effective with an incremental cost-effectiveness ratio lower than $13 000 per QALY gained.

Effect of Discount Rate. Analyses assuming discount rates of 0% and 5% in addition to the baseline assumption of 3% were conducted. These variations in the discount rate did not have a large impact on the cost-effectiveness ratios. A discount rate of 0% led to an incremental cost-effectiveness ratio for core decompression of $12 429 per QALY gained. A discount rate of 5% resulted in a ratio of $9620 per QALY gained. These ratios fall well below the threshold of $50 000 per QALY commonly used to judge procedures as moderately cost-effective [12].

Discussion

The purpose of this analysis is to assist orthopedic surgeons in judging whether currently available data justify the use of core decompression of the hip as cost-effective. This study found core decompression to have the potential to be a highly cost-effective choice when it is assumed to successfully delay symptoms and the need for hip arthroplasty for 5 years or longer. This delay improves quality of life at a small additional cost by delaying the expense and risks for THA. However, these results depend on clinical outcomes after core decompression not yet demonstrated definitively in well-designed studies. Limited data exist in the literature documenting successful results in controlled trials at 5- and 10-year follow-up on patients that have undergone core decompression of the hip. Existing studies have indicated promising results that meet or exceed these goals after core decompression, but control groups are often inadequate [1-11]. More rigorous evaluation of core decompression is required to document its true efficacy and resulting cost-effectiveness.

The conclusions of this cost-effectiveness analysis are limited by the accuracy of the underlying assumptions used to design the model and assign values for effectiveness and costs. Sensitivity analysis demonstrated that the key variable that impacts the results of this study was the assumed duration that core decompression delays symptoms and the need for primary hip arthroplasty. In the reference case of our study, core decompression resulted in a cost-effectiveness ratio of $9551 per QALY gained when chosen over observation. This cost-effectiveness ratio compares favorably to other medical and surgical interventions. The cost-effectiveness ratio rises and the level of cost-effectiveness diminishes when the period of delay before hip arthroplasty is assumed to be shorter than the reference case assumption of 10 years. The cost-effectiveness ratio of core decompression rises to more than $50 000 per life year as this interval falls below 5 years.

Specific thresholds for determining favorable cost-effectiveness ratios have not been established. However, several authors have suggested that cost-effectiveness ratios more than $50 000 per life year gained are indicative of interventions with limited cost-effectiveness [12]. An examination of THA demonstrated a cost-effectiveness ratio of $4600 (1991 US dollars) per QALY [37]. The authors

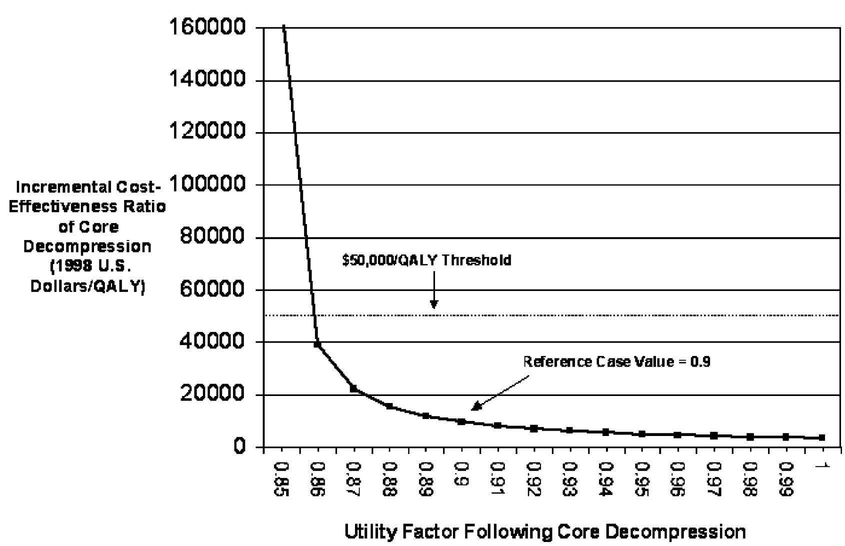


Fig. 3. Sensitivity analysis examining relationship between functional utility after core decompression and its incremental cost-effectiveness ratio.

concluded that this ratio supported hip arthroplasty as a highly cost-effective procedure. They cite examples of other medical interventions widely accepted as cost-effective, including coronary artery bypass grafting ($8100 per QALY). This study demonstrates the potential of core decompression to result in a similar level of cost-effectiveness when compared with observation if it delays the need for hip arthroplasty for a minimum of 5 years [12].

Sensitivity analysis also highlighted the importance of the ability of core decompression to preserve hip function and its impact on cost-effectiveness. The reference case assumes that the utility of patients after core decompression remains high before the need for hip arthroplasty. The published literature focuses on radiographic outcomes and does not thoroughly document the quality of life of patients after core decompression. Patients may have a gradual deterioration in function before they require THA. Sensitivity analyses demonstrated that when hip function is assumed to deteriorate during this period and result in utilities lower than 0.86, the cost-effectiveness ratio of core decompression rises to more than $50 000 per QALY gained and the cost-effectiveness advantages of core decompression become minimal.

These sensitivity analyses suggest that the cost-effectiveness of core decompression is limited when it delays hip arthroplasty less than 5 years. The literature has established that patients with post-collapse osteonecrosis do not reliably achieve results above this threshold after core decompression. As a result, core decompression is likely to have poor cost-effectiveness in these cases of late-stage disease. Patients with extensive femoral head involvement or a history of long-term steroid use are also likely to demonstrate clinical efficacy below these levels [3-11]. The use of core decompression in these subgroups is not supported in this analysis.

This study supports core decompression as a potentially cost-effective choice over observation in the early stages of osteonecrosis of the hip. This conclusion relies on the assumption that core decompression delays hip arthroplasty and prevents painful symptoms for a minimum of 5 years. Current data have not yet definitively shown in well-designed trials that core decompression predictably results in these levels of clinical efficacy. However, existing studies indicate promising results that meet or exceed these goals after core decompression in patients with small lesions who are not being treated with steroids [1,2]. The cost-effective indications for continued use of this procedure in early-stage disease will be more clearly delineated when results above this threshold are documented in controlled long-term clinical trials.

Appendix A. Summary of Literature Search and Abstracted Data

A.1. Summary of Literature Search

A.1.1. Search Strategy.

Keywords (in permutation)	*Osteonecrosis, decompression, hip, outcome*
Dates	1978-2004
Total articles	269
Articles not relevant	191
Relevant articles analyzed	78
Excluded reviews	15
Excluded articles <50 subjects	30
Excluded articles that failed criteria	22
Articles remaining from 78	11

A.1.2. Randomized Control Trial Used for Core Decompression and Conservative Treatment

A.1.2.1. Randomized control trial, more than 50 subjects

- Ref [3].

A.1.3. Articles Used for Core Decompression

A.1.3.1. Prospective, more than 50 subjects[1]

- Refs [4-9].

A.1.3.2. Retrospective, more than 50 subjects

- Refs [10,11].

A.1.4. Articles Used for Conservative Treatment.

- Refs [21,22].

A.2. Abstracted Data

A.2.1. Randomized Controlled Trial Data.

- Ref [3].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Randomized control trial	55	26.8	18-"not reported"

[1]All articles have greater than 50 subjects, with the exception of the study of Aigner et al [4], which was included based on having 45 subjects and meeting all other quality criteria.

Survival
Ficat stage I

	Month 10	Month 20	Month 40	Month 60
Survival, operative	0.90	0.65	0.65	0.65
Survival, nonoperative	0.60	0.60	0.20	0.20

Ficat stage II

	Month 10	Month 20	Month 40	Month 60
Survival, operative	1.00	0.70	0.70	0.70
Survival, nonoperative	0.55	0.15	0	0

Ficat stage III

	Month 10	Month 20	Month 40	Month 60
Survival, operative	1.00	0.725	0.725	0.725
Survival, nonoperative	0.325	0.20	0.20	0.20

Outcomes
Success is measured as a Harris Hip Score of more than 80.

Ficat stages	Success rate operated hips	Success rate nonoperated hips
I	0.70	0.20
II	0.71	0
III	0.73	0.10

Complications
Not reported.

A.2.2. Prospective Core Decompression Data.
• Ref [4].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Prospective	45	69	31-120

Survival
Failure is defined as deterioration to ARCO stage IV.

ARCO stages	Success rate	Mean time (mo)
I	0.93	69
II	0.44	69.2
III	0	72

ARCO indicates Association Internationale de Recherchesur la Circulation Osseuse.

Outcomes
Measured with Harris Hip Score

Variable	ARCO I (n = 30)	ARCO II (n = 9)	ARCO II (n = 6)
Excellent	0.90	1.00	
Good	0		
Fair	0.10	0	
Poor	0	0	1.00

Complications

Complication	Probability
Hip fracture	0
Infection	0
DVT	0.02
Pulmonary embolism	0
Hematoma	0

DVT indicates deep venous thrombosis.

• Ref [5].
In this study, the reported staging is a combination of Steinberg stages with Ficat and Arlet stages.

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Prospective	54	120	24-196

Survival
Clinical failure is defined as requiring subsequent surgery.

	Month 12	Month 24	Month 48	Month 96	Month 132
Stage I	1.00	0.925	0.925	0.925	0.925
Stage IIA sclerotic	1.00	1.00	1.00	1.00	1.00
Stage IIA cystic/sclerocystic	0.825	0.675	0.625	0.40	0.40
Stage IIB	0.60	0.40	0.40	0.40	0.40
Stage III	0.375	0.375	0.25	0	0

Outcomes
Not reported.
Complications

Complication	Probability
Hip fracture	0.019
Infection	0
DVT	0
Pulmonary embolism	0
Hematoma	0.019

• Ref [6].
This study is unique in that it has survival data according to 4 different staging systems: Ficat, U Penn, ARCO, and Florida.

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Prospective	67	40.7	1.5-48

Survival
Failure is defined as progression to THA.

	Ficat	U Penn	ARCO	Florida
I	0	0	0	0
II	0.17	0.19	0.217	0.20
III	0.66	0.50	0.35	0.40

Outcomes
Mean Harris Hip Score postoperatively is 58.5 for the whole cohort.
Complications

Complication	Probability
Hip fracture	0
Infection	0
DVT	0.015
Pulmonary embolism	0
Hematoma	0

• Ref [7].
This covers data only for core decompression.

Study design	Hips in article	Mean follow-up	Follow-up range
Prospective	94	Not reported	Not reported

Survival
Failure is defined as any further surgery.

	12 mo	24 mo	36 mo	48 mo	60 mo	72 mo
Survival, Steinberg 0, I, II (n = 32)	1.00	0.925	0.85	0.84	0.78	0.78
Survival, Steinberg III, IV, V (n = 23)	0.775	0.75	0.65	0.63	0.65	0.56

Outcomes
Not reported.
Complications
Not reported.
• Ref [8].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Prospective	406	48	3-155

Survival

Steinberg stages	Success rate	Mean time (mo)
0, I, II	0.163	29
III, IV, V	0.11	29

	Year 1	Year 2	Year 3	Year 5	Year 10
Survival	0.93	0.83	0.79	0.75	0.73

Outcomes
Only the mean outcome is reported. Outcomes by category (ie, excellent, good, fair, poor) are not reported.
Complications

Complication	Probability
Hip fracture	0.005
Infection	0
DVT	0.002
Pulmonary embolism	0.002
Hematoma	0

• Ref [9].
The following definitions apply:

Small lesion, less than 15% of femoral head involvement;
Moderate lesion, 15% to 30% of femoral head involvement;
Large lesion, greater than 30% of femoral head involvement.

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Prospective	73	39	24-72

Survival

	Small lesion	Moderate lesion	Large lesion
Survival, U Penn stage I	0	0.25	0.50
Survival, U Penn stage II	0.09	0.33	0.31

U Penn indicates University of Pennsylvania Staging System.

Outcomes
Absolute Harris Hip Score is not reported. Postoperative change in Harris Hip Score is reported

	Small lesion	Moderate lesion	Large lesion
Change in Harris Hip Score, U Penn stage I	+14.3	+5.0	−12.0
Change in Harris Hip Score, U Penn stage II	+9.3	+2.6	−2.9

Complications
Not reported.

A.2.3. Retrospective Core Decompression Data.

• Ref [10].

The following definitions apply:

Small lesion, less than 15% of femoral head involvement;
Moderate lesion, 15% to 30% of femoral head involvement;
Large lesion, greater than 30% of femoral head involvement.

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Retrospective	328	46	1-156

Survival

	Small lesion	Moderate lesion	Large lesion
Survival, U Penn stage I	0.10	0.53	0.60
Survival, U Penn stage II	0.16	0.43	0.36

	U Penn stage I	U Penn stage II	U Penn stage III	U Penn stage IV
Survival	0.70	0.66	0.71	0.52

Outcomes

Only the Harris Pain Score is reported. The total Harris Hip Score is not reported.

Complications

Not reported.

• Ref [11].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Retrospective	94	72	18-180

Survival

Hips that had risk factors such as heavy alcohol use, corticosteroid use, and others are included in these survival statistics.

	24 mo	48 mo	72 mo
Survival, Steinberg 0, I, II	0.825	0.55	0.50
Survival, Steinberg III, IV, V	0.633	0.35	0.28

Outcomes

Merle d'Aubigne Scores were reported but not for all levels (ie, poor, fair, good, excellent).

Complications

Complication	Probability
Hip fracture	0.02
Infection	0.02
DVT	0
Pulmonary embolism	0.02
Hematoma	0

A.2.4. Conservative Treatment Data.

• Ref [21].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Retrospective	50	16	1-43

Survival

Not reported comprehensively.

Outcomes

Group A, continued conservative treatment
Group B, indication for surgery

	No. of hips	Mean Merle d'Aubigne at end point	Change in Merle d'Aubigne
Outcome, group A	9	11.9	−2.8
Outcome, group B	41	10.1	−3.8
Outcome, A + B	50	10.3	−3.6

Complications

Not reported.

Ref [22].

Study design	Hips in article	Mean follow-up (mo)	Follow-up range (mo)
Retrospective	115	63	1-216

Survival

Type 1, characterized by the presence of a demarcation line around the necrotic area in femoral head
Type 2, early flattening of weight-bearing surface but has no demarcation line
Type 3, cystic lesions present in femoral head

	No. of hips	No. of collapse	Incidence
Survival type 1	89	67	0.75
Survival type 2	4	4	1.00
Survival type 3	22	7	0.32

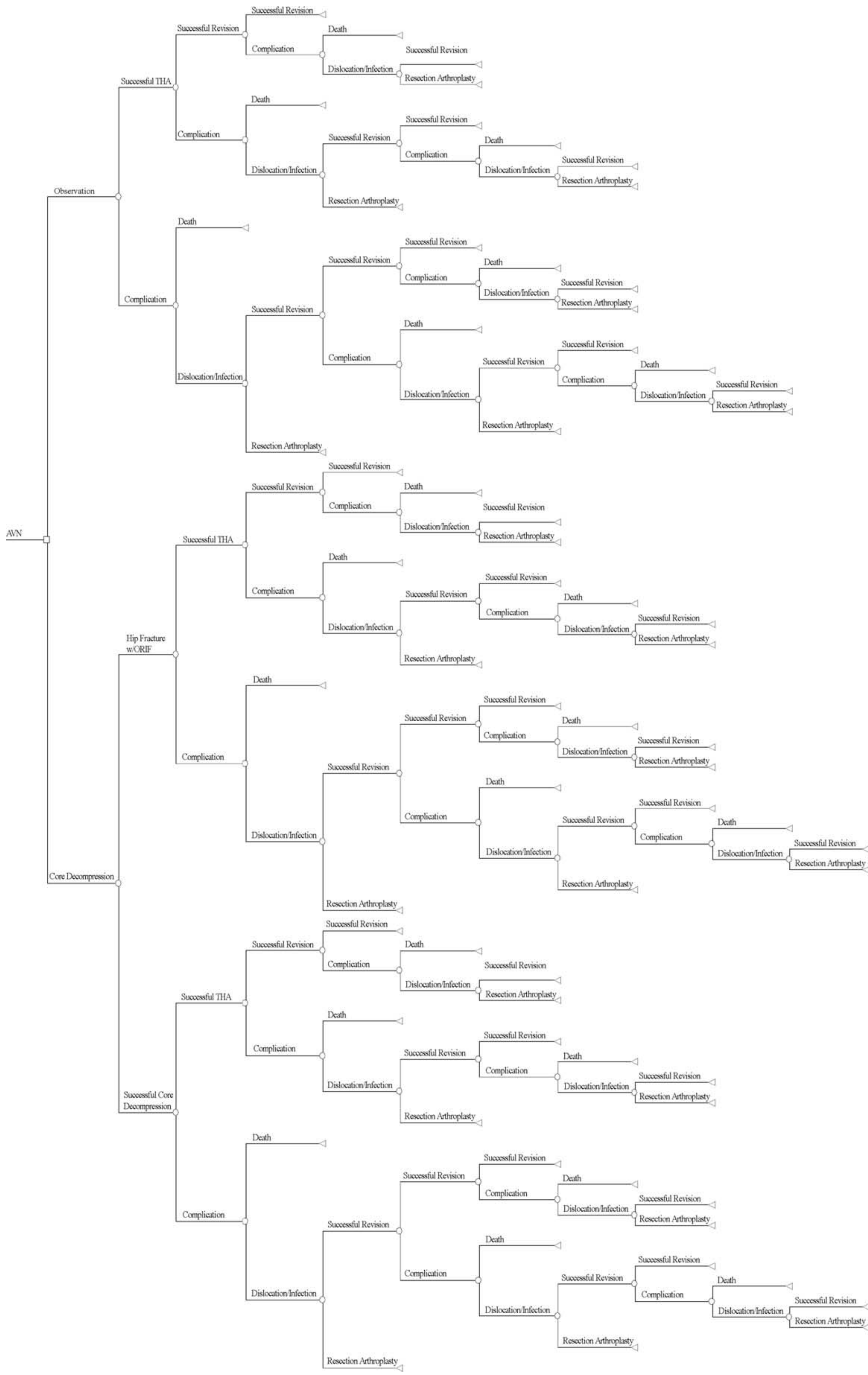
Outcomes

Not reported.

Complications

Not reported.

Appendix B


AVN
Observation
Successful THA
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Resection Arthroplasty
Resection Arthroplasty
Core Decompression
Hip Fracture w/ORIF
Successful THA
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Resection Arthroplasty
Resection Arthroplasty
Successful Core Decompression
Successful THA
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
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Dislocation/Infection
Successful Revision
Resection Arthroplasty
Complication
Death
Dislocation/Infection
Successful Revision
Successful Revision
Complication
Death
Dislocation/Infection
Successful Revision
Resection Arthroplasty
Resection Arthroplasty
Resection Arthroplasty

References

1. Lieberman JR, Berry DJ, Mont MA, et al. Osteonecrosis of the hip: management in the twenty-first century. J Bone Joint Surg 2002;84-A:834.
2. Lavernia CJ, Sierra RJ, Grieco FR. Osteonecrosis of the femoral head. J Am Acad Orthop Surg 1999;7:250.
3. Stulberg BN, Davis AW, et al. Osteonecrosis of the femoral head. A prospective randomized treatment protocol. Clin Orthop Relat Res 1991;268:140.
4. Aigner N, et al. Core decompression in early stages of femoral head osteonecrosis—an MRI-controlled study. Int Orthop 2002;26:31.
5. Bozic KJ, Zurakowski D, Thornhill TS. Survivorship analysis of hips treated with core decompression for nontraumatic osteonecrosis of the femoral head. J Bone Joint Surg 1999;81:200.
6. Lavernia CJ, Sierra RJ. Core decompression in atraumatic osteonecrosis of the hip. J Arthroplasty 2000;15:171.
7. Simank HG, et al. Comparison of results of core decompression and intertrochanteric osteotomy for nontraumatic osteonecrosis of the femoral head using Cox regression and survivorship analysis. J Arthroplasty 2001;16:790.
8. Steinberg ME, et al. Core decompression with bone grafting for osteonecrosis of the femoral head. Clin Orthop Relat Res 2001;386:71.
9. Steinberg ME, et al. Does lesion size affect the outcome in avascular necrosis? Clin Orthop Relat Res 1999;367:262.
10. Belmar CJ, Steinberg ME, Hartman-Sloan KM. Does pain predict outcome in hips with osteonecrosis? Clin Orthop Relat Res 2004;425:158.
11. Simank HG, et al. Core decompression in osteonecrosis of the femoral head: risk-factor–dependent outcome evaluation using survivorship analysis. Int Orthop 1999;23:154.
12. Gold MR, Siegel JE, Russell LB, et al. Cost-effectiveness in health and medicine. New York: Oxford University Press; 1996.
13. Weinstein MC, Stason WB. Foundations of cost-effectiveness analysis for health and medical practices. N Engl J Med 1977;296:716.
14. Bozic KJ, Rosenberg AG, Huckman RS, Herndon JH. Current concepts review: economic evaluation in orthopaedics. J Bone Joint Surg 2003;85-A:129.
15. Detsky AS, Naglie G, Krahn MD, et al. Primer on medical decision analysis: part 1—getting started. Med Decis Making 1997;17:123.
16. Detsky AS, Naglie G, Krahn MD, et al. Primer on medical decision analysis: part 2—building a tree. Med Decis Making 1997;17:126.
17. Naglie G, Krahn MD, Naimark D, et al. Primer on medical decision analysis: part 3—estimating probabilities and utilities. Med Decis Making 1997;17:136.
18. Krahn MD, Naglie G, Naimark D, et al. Primer on medical decision analysis: part 4—analyzing the model and interpreting the results. Med Decis Making 1997;17:142.
19. Redelmeier DA, Detsky AS, Krahn MD, et al. Guidelines for verbal presentations of medical decision analyses. Med Decis Making 1997;17:228.
20. Anderson RN, DeTurk RB. United State life tables 1999. Natl Vital Stat Rep 2002;50:1.
21. Musso ES, et al. Results of conservative management of osteonecrosis of the femoral head. A retrospective review. Clin Orthop Relat Res 1986;207:209.
22. Ohzono K, et al. Natural history of nontraumatic avascular necrosis of the femoral head. J Bone Joint Surg Br 1991;73-B:68.
23. Huo MH, Brown BS. Specialty update: what's new in hip arthroplasty? J Bone Joint Surg 2003;85-A:1852.
24. Virolainen P, et al. The reliability of diagnosis of infection during revision arthroplasties. Scand J Surg 2002;91:178.
25. Salvati EA, Robison RP, Zeno SM, et al. Infection rates after 3175 total hip and total knee replacement performed with and without horizontal unidirectional filtered air flow system. J Bone Joint Surg 1982;64A:525.
26. Mohamed NN, et al. Rates and outcomes of primary and revision total hip replacement in the United States Medicare population. J Bone Joint Surg Am 2003;85-A:27.
27. Phillips CB, et al. Incidence rates of dislocation, pulmonary embolism, and deep infection during the first six months after elective total hip replacement. J Bone Joint Surg Am 2003;85-A:20.
28. Spangehl MJ, Younger ASE, Masri BA, et al. Instructional course lectures, the American Academy of Orthopaedic Surgeons—diagnosis of infection following total hip arthroplasty. J Bone Joint Surg Am 1997;79-A:1578.
29. Kreder HJ, Deyo RA, Koepsell T, et al. Relationship between the volume of total hip replacements performed by providers and the rates of postoperative complication in the state of Washington. J Bone Joint Surg Am 1997;79-A:485.
30. Fryback DG, Dasbach EJ, Klein R, et al. The beaver dam health outcomes study: initial catalog of health-state quality factors. Med Decis Making 1993;13:89.
31. Tengs TO, Wallace A. One thousand health-related quality-of-life estimates. Med Care 2000;38:583.
32. Gold MR, Franks P, McCoy KI, et al. Toward consistency in cost-utility analyses: using national measures to create condition-specific values. Med Care 1998;36:778.
33. Gold M, Franks P, Erickson P. Assessing the health of the nation: the predictive value of a preference-based measure and self-rated health. Med Care 1996;34:163.
34. The DRG handbook. New York: Ernst & Young LLP; 1999.
35. Lave JR, et al. Costing medical care: using Medicare administrative data. Med Care 1994;32:JS77.
36. Final rule of Medicare program's fee schedule for physicians' services for calendar year 1998. Federal Register.
37. Chang RW, Pellissier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. JAMA 1996;275:858.