Economic Evaluation in Total Hip Arthroplasty
Analysis and Review of the Literature

Kevin J. Bozic, MD, MBA,* Khaled J. Saleh, MD, MSc,† Aaron G. Rosenberg, MD,‡ and Harry E. Rubash, MD§

Abstract: We performed a bibliographic search of MEDLINE databases from January 1966 to July 2002 to identify English language articles that contained either “cost” or “economic” in combination with “total hip arthroplasty” (THA) in the abstract or title. Each study was then critically reviewed for content, technique, and adherence to established healthcare economic principles. Only 81 of the 153 studies retrieved contained actual economic data. Only 6% of studies adhered to established criteria for a comprehensive health care economic analysis. Although the number of publications regarding economic evaluation of THA is on the rise, the methodologic quality of many of these studies remains inadequate. Future studies should employ sound healthcare economic techniques to properly evaluate and assess the true social and economic value of THA. Key words: total hip arthroplasty, economic analysis, literature review.

© 2004 Elsevier Inc. All rights reserved.

Total hip arthroplasty (THA) has emerged as one of the most successful interventions in orthopaedics. Many long-term follow-up studies have reported clinical success rates, in terms of patient satisfaction, pain reduction, functional improvement, and the absence of further surgery, of greater than 90% at minimum 10-year follow-up evaluation [1]. Furthermore, THA compares favorably with other health care interventions in terms of cost per quality-adjusted life year (QALY) gained and other measures of health utility [2,3].

Despite these encouraging results, rising health care costs and diminishing health care resources have forced orthopaedic surgeons and other health care professionals to develop innovative ways to provide cost-efficient, high-quality care. In response to these economic pressures, numerous investigations have been performed pertaining to economic evaluation of healthcare interventions. Orthopaedic surgeons have also begun to use this type of research as a tool to document the comparative cost effectiveness and cost utility of certain orthopaedic procedures.

The number of research publications devoted to economically related topics regarding THA has increased dramatically over the past 15 years [4] (Table 1). However, the methodology used and the quality of these reports varies considerably. The usefulness of this type of research to the orthopaedic community is highly dependent on the investigators’ access to accurate economic data and adherence to sound health care economic principles [5,6].

Guidelines to establish the validity of healthcare economic analyses have been published throughout.
Table 1. Number of Economic Evaluations Relating to Total Hip Arthroplasty Published in the English Literature, by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Studies (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>1</td>
</tr>
<tr>
<td>1981</td>
<td>0</td>
</tr>
<tr>
<td>1982</td>
<td>0</td>
</tr>
<tr>
<td>1983</td>
<td>1</td>
</tr>
<tr>
<td>1984</td>
<td>0</td>
</tr>
<tr>
<td>1985</td>
<td>1</td>
</tr>
<tr>
<td>1986</td>
<td>1</td>
</tr>
<tr>
<td>1987</td>
<td>0</td>
</tr>
<tr>
<td>1988</td>
<td>1</td>
</tr>
<tr>
<td>1989</td>
<td>1</td>
</tr>
<tr>
<td>1990</td>
<td>2</td>
</tr>
<tr>
<td>1991</td>
<td>2</td>
</tr>
<tr>
<td>1992</td>
<td>1</td>
</tr>
<tr>
<td>1993</td>
<td>3</td>
</tr>
<tr>
<td>1994</td>
<td>6</td>
</tr>
<tr>
<td>1995</td>
<td>5</td>
</tr>
<tr>
<td>1996</td>
<td>6</td>
</tr>
<tr>
<td>1997</td>
<td>8</td>
</tr>
<tr>
<td>1998</td>
<td>16</td>
</tr>
<tr>
<td>1999</td>
<td>8</td>
</tr>
<tr>
<td>2000</td>
<td>8</td>
</tr>
<tr>
<td>2001</td>
<td>8</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
</tr>
</tbody>
</table>

Materials and Methods

A comprehensive review of the literature was performed using a computerized bibliographic search of MEDLINE databases from January 1966 to July 2002. English-language articles were retrieved that contained the words “cost” or “economic” in combination with “hip arthroplasty” in either the abstract or the title.

Inclusion Criteria

From this list, studies were selected that met established criteria for one of the following 4 types of healthcare economic evaluation, as defined by Robinson [9] (all of which are defined in further detail in later sections): cost-identification (minimization) analysis, cost-effectiveness analysis, cost-utility analysis, and cost-benefit analysis. Each publication that met the established guidelines for one of these types of analyses was then critically reviewed for content and technique. Data collected from each study included the subject of the investigation, the perspective taken, the source and type of cost data used, the time-horizon considered, the use of cost-effectiveness ratios (or other summary measures), and the use of discounting and sensitivity analysis techniques. Each study was also reviewed for adherence to the principles recommended by Udvarhelyi et al. [5] as a minimum standard for performing and reporting a comprehensive healthcare economic evaluation:

1.) An explicit statement of a perspective for the analysis should be provided. 2.) An explicit description of the benefits of the program or technology being studied should be provided. 3.) Investigators should specify what types of costs were used or considered in their analysis. 4.) If costs and benefits accrue during different periods, discounting should be used to adjust for the differential timing. 5.) Sensitivity analyses should be performed to test important assumptions. 6.) A summary measurement of efficiency, such as a cost-benefit or cost-effectiveness ratio, should be calculated and preferably expressed in marginal or incremental terms unless one alternative or strategy is dominant.

Explanation of Terms

Cost Identification (Minimization) Analysis. Most health economists consider cost identification analysis to be the simplest form of healthcare economic evaluation. The costs included in the analysis vary depending on the perspective considered in the study. This method considers only the inputs (or costs) of a given treatment strategy. The assumed goal of a cost-minimization analysis is to find the least-expensive way to achieve the same outcome [11]. By definition, a cost-minimization study assumes that the outcomes of the treatments under consideration are equal [12], which is rarely the case. In this review, any publication that contained cost data, regardless of the source of the data, but did not include any measurement of or correlation with outcome measures was labeled as a cost-identification study.

Cost-effectiveness Analysis. A cost-effectiveness analysis measures health outcomes in physical or “natural” units, such as life-years gained or cases successfully treated. No attempt is made to place a subjective value on the health outcomes that are reported. This is an appropriate technique to use when the outcomes of different procedures being considered may be expected to vary, but these outcomes can be expressed in common natural
units [13]. Any publication that attempted to correlate cost with an objective outcome measure (such as cost per complication prevented, not a subjective measurement of health utility) or reported calculation of a cost-effectiveness ratio was classified as a cost-effectiveness analysis.

**Cost-utility Analysis.** In cost-utility analyses, outcomes of different types are expressed in terms of a single utility-based unit of measurement. Utility is a term used by health economists to describe the subjective level of well being that people experience in different states of health [14]. Measuring utilities allows valid comparisons among treatment options, and utilities are often used for the purposes of decision analysis. This type of analysis is particularly useful when alternative treatments produce outcomes of different types or when increased survival is bought at the expense of reduced quality of life. Any study that reported cost-utility measurements, such as cost-QALY, was classified as a cost-utility analysis.

**Cost-benefit Analysis.** In a cost-benefit analysis, all inputs and outputs (such as health outcomes) are measured in monetary terms. Health consequences are valued by asking healthcare consumers what they would be willing to pay for health services that achieve a particular health outcome or state of health [8]. The advantage of this type of approach is that it makes possible comparisons of interventions across subspecialties, because all costs and outcomes are valued in the same monetary units. Any study that attempted to assign a monetary benefit to a particular health care intervention or health outcome, in addition to providing cost input data, was classified as a cost-benefit analysis.

**Perspective.** Economic data can be analyzed from different perspectives, including that of the patient, the hospital, the payer, the physician, the surgical device manufacturer, or society as a whole. The perspective chosen in performing the analysis should be explicitly stated and justified so that the reader can better interpret the results and evaluate the appropriateness of other methodologic decisions made by the investigator [8]. The perspective chosen will also reflect the type of decisions supported by the analysis and the relevant health outcomes and resources and how they should be measured and valued [6,10].

**Costs.** Direct costs include the value of all medical and nonmedical resources directly related to the intervention, including personnel, supplies, and facility costs involved in the treatment of a patient [6]. Indirect costs include costs associated with lost productivity, illness, or death, usually valued as lost wages or an imputed monetary value of time [7]. This definition should not be confused with the traditional accounting definition of indirect costs that refers to fixed overhead costs.

**Time Horizon.** The time horizon of a healthcare economic evaluation is the period of time for which costs and outcomes are measured [6]. The time horizon being considered should be specified and justified as being appropriate for the clinical condition being studied and the expected costs and benefits of the treatment program [15]. Investigators should bear in mind the trade-off between allowing adequate follow-up to capture all of the relevant costs and clinical outcomes, while providing results within a reasonable period of time [16].

**Discounting.** Discounting refers to the process of converting future costs and future health outcomes to their present value [6]. In health care, benefits and costs often accrue over different periods of time and for different durations of time [5]. Therefore, during performance of a healthcare economic evaluation, both the costs and benefits associated with a specific intervention should be “discounted back” to a common point in time, to allow a valid comparison between treatment regimens.

**Sensitivity Analysis.** Sensitivity analysis involves changing one or more of the variables under consideration to examine the degree of influence each factor has on the outcome of the entire analysis [17]. It is a technique that is widely used in economic evaluations to assess how the strength and validity of the conclusions of a study vary with changes in the underlying assumptions and estimates [5]. Sensitivity analyses allow the reader to judge the effect on study results of alternative assumptions for the range of potential values for uncertain parameters [7].

**Results**

The initial search recovered 153 English language publications containing either “cost” or “economic” and “hip arthroplasty” in the title or abstract. Of these, only 81 contained actual economic data and therefore could be classified as one of the 4 types of economic analyses described previously [1–4,18–97].

**Type of Economic Evaluation**

Of the 81 economic analyses identified, 47 (58%) were classified as cost-identification analyses, 20 (25%) as cost-effectiveness analyses, 13 (16%) as cost-utility analyses, and 1 study (1%) was classified as a cost-benefit analysis (Fig. 1).
Subject of Investigation

Of the 81 studies reviewed, 48 dealt with either the cost of the implants or the procedure (for example, total hip arthroplasty) itself (Fig. 2). Other topics that were analyzed included deep venous thrombosis (DVT) prophylaxis (14 studies), blood salvage (7 studies), drugs (2 studies), postoperative radiographs (2 studies), intraoperative pathology (2 studies), rehabilitation (2 studies), preoperative laboratory studies (1 study), heterotopic ossification prophylaxis (1 study), early operative intervention for osteolysis (1 study), and the use of drains (1 study).

Perspective

The vast majority of studies (80%) were performed from the perspective of the hospital or the payer (Table 2). We found that 17% of studies, including 62% of the cost-utility studies, were performed from a societal perspective. Other perspectives considered included the physician (3 studies), the patient (2 studies), and the implant manufacturer (1 study). Fourteen of the 81 studies reviewed considered more than one perspective.

Costs Considered

Seventy-two studies (89%) considered only direct costs in their analysis, and 21 studies (26%) included estimates regarding the direct costs of follow-up care, including costs for the treatment of complications or revision surgery (Fig. 3). Eight of 13 (62%) of cost-utility studies included estimates of indirect costs, and only 9% of cost-identification studies and 5% of cost-effectiveness studies considered indirect costs.

Source of Costs

Only 60 of 81 of studies (74%) specified the source of economic data (Fig. 4). Of these, 25 (31%) reported patient-specific or mean charges and 6 (7%) used cost-to-charge ratios. Ten studies (12%) used cost data obtained from the literature. Seven studies (9%) used knowledge-based accounting systems that attempt to more accurately allocate costs. Only 3 studies (4%) used actual cost data collected in a prospective manner. Five studies...
(6%) used patient diaries to estimate indirect costs incurred by patients.

**Time Horizon**

The majority of studies (62%) considered costs involved during the initial hospitalization or rehabilitation stay only (Fig. 5). Only 13 studies (16%) had a time horizon of more than 1 year.

**Discounting and Sensitivity Analysis**

Only 10 studies (12%) employed discounting techniques to discount cost or outcome data, including 5 of 13 (38%) of cost-utility studies (Table 3). Eighteen studies (22%) performed sensitivity analyses to test the validity and versatility of the conclusions, including 50% of cost-effectiveness analyses and 62% of cost-utility analyses.

**Methodologic Quality**

Only 6 of the 81 studies reviewed (7%) met all 6 criteria recommended by Udvarhelyi et al. [5] (described previously) for a comprehensive healthcare economic analysis (Table 4).

**Discussion**

Recent trends in health care, including rising costs and increased constraints on economic resources, have led to increased emphasis on healthcare economic evaluation. The importance of economic research has been recognized by the orthopaedic community and is reflected in the growing number of publications that have been dedicated to this subject over the past two decades [4,47].

Although the number of publications regarding economic issues related to THA is on the rise, most studies are simple cost-identification analyses that do not employ sophisticated healthcare economic evaluative techniques. Furthermore, the methodologic quality of many of these studies remains questionable. The majority of the comprehensive, well-designed cost-effectiveness and cost-utility studies on orthopaedic-related topics have been published in journals outside of the mainstream orthopaedic literature [32,43,44,54,94]. In our review, although 83% of cost-minimization analyses were published in journals devoted primarily to orthopaedic topics, only 40% of cost-effectiveness and 27% of cost-utility analyses were published in orthopaedic-related journals.

In this study, we found that only a minority (17%) of economic evaluations pertaining to THA were performed from a societal perspective. A more
focused perspective, such as that of the hospital or the payer, may be appropriate when evaluating the costs associated with a particular implant or device. However, to fully understand the full costs and benefits of an intervention such as THA, a more broad perspective should be considered, such as that of society as a whole [6,8].

The vast majority of studies we reviewed (89%) considered only direct costs that were incurred during the initial perioperative period. In certain cases, such as an analysis of treatment options for deep venous thrombosis prophylaxis, considering only the initial direct costs may be sufficient. However, to provide a more accurate estimate of the overall costs associated with THA, future studies should attempt to measure the total costs of THA, including indirect costs incurred by patients (and society) and downstream costs associated with complications or the need for further intervention, such as revision surgery.

Only 3 studies that we reviewed used actual cost data obtained during prospective clinical trials. Briggs [98] emphasized the importance of including economic variables in the original study design, rather than “piggybacking” them onto an existing clinical trial, because cost variables generally have a higher variance than clinical outcomes. Therefore, economic evaluations require greater sample sizes than the corresponding clinical comparison. By “piggybacking” an economic analysis alongside an existing clinical trial, the results of both the cost analysis and cost-effectiveness analysis will often be underpowered, thereby calling into question the validity and usefulness of the results [98]. Other authors have warned against using charge data or cost-to-charge ratios as a proxy for costs, given the poor correlation between these data and the true economic costs associated with a procedure [6,8].

Very few studies we reviewed used discounting techniques or sensitivity analysis. For studies that consider a relatively short time horizon, such as the cost-effectiveness of routine pathologic examination of intraoperative specimens [66], it may not be necessary to discount the costs or benefits measured. However, if the goal of a study is to evaluate the cost per QALY gained of THA, discounting techniques are important to make valid comparisons between treatments that result in benefits that accrue over long periods of time. Furthermore, providing a sensitivity analysis allows the reader to assess the strength and versatility of the conclusions of the study.

In our review, only 6 of 81 studies reviewed (7%) adhered to the criteria established by Udvarhelyi et al. [5] as a minimum standard for performing and reporting a healthcare economic analysis. This may be due in part to the large number of cost-identification studies that were reported, which in many cases did not explicitly state the perspective of the analysis or the types of costs that were considered.

The well-designed cost-effectiveness and cost-utility analyses that have been published have reported encouraging results regarding the economic benefits of THA. In a comprehensive cost-utility study published in JAMA, Chang et al. [32] reported a cost-QALY gain of $4,600 less than that of coronary artery bypass surgery or renal dialysis. The authors concluded that for persons with hip osteoarthritis associated with significant functional limitation, THA can be cost saving or, at worst, cost effective in improving quality of life expectations when both short- and long-term outcomes are considered.

In a Finnish study, Rissanen et al. [84] prospectively compared costs and cost-effectiveness in THA and total knee arthroplasty (TKA) patients. They reported that, on average, THA patients gained more in terms of health-related quality of life, and
the surgeries were more cost effective (average cost-QALY of $6,153) versus TKA (average cost-QALY of $10,413). Liang et al. [74] reviewed the costs and benefits of THA and TKA in consecutive patients 6 months after surgery. They found that at 6 months postoperatively, the cost-effectiveness ratio was associated with initial health status, and the highest ratios were seen in patients who had the poorest preoperative health.

In a study from Canada, Rorabeck et al. [87] compared the costs of cemented versus cementless THA in a well-designed, prospective, randomized study of 250 patients with osteoarthritis of the hip. They included both direct and indirect costs in the analysis and performed the study from a broad (societal) perspective. The authors reported similar costs per QALY in both groups (CA $17,915 QALY gained for cemented versus CA $18,398 for cementless), which compares favorably with other health care interventions [87].

Gillespie et al. [49] used published survival data from Sweden and cost and demographic data from Australia in a sophisticated economic model to compare the potential cost effectiveness of various new cemented prosthetic designs. They found that in young, active THA patients, a new prosthetic design would have to guarantee a 90% improvement in survivorship over 15 years and a 15% reduction in the cost of revision surgery to justify a price of 2 to 2.5 times that of “conventional” cemented components, such as the Charnley low friction arthroplasty, and still be cost effective. In older patients, only a very small increase in the cost of a prosthesis could ever be justified, because of shorter life expectancy and high survivorship of the implant.

The importance and relevance of economic evaluation of THA is apparent from the growing number of papers devoted to the subject. Nevertheless, the majority of these reports are simple cost-minimization studies, which limits the usefulness of their conclusions and precludes comparison of THA to other health care interventions. Very few studies use more sophisticated healthcare economic techniques such as cost-effectiveness or cost-utility analysis, and even fewer studies adhere to the accepted principles of a comprehensive economic evaluation [5]. An example of a well-designed economic evaluation to assess the cost-effectiveness of THA is proposed in (Table 5).

The lack of well-designed economic evaluations related to THA could be caused by a number of factors. First, very few orthopaedic surgeons have formal training in healthcare economic evaluation. Also, orthopaedic surgeons may have difficulty accessing hospital and clinic financial data, because of competitive concerns among payers and institutions. Furthermore, healthcare economic data can be difficult to interpret, because of variations in costs and charges that occur as a result of geographic, temporal, and accounting system differences. Finally, given that the costs and benefits associated with THA accrue over a period of many years and even decades, the duration and costs

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost/QALY (£ as of August 1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol testing and diet therapy only (all adults aged 40–69)</td>
<td>220</td>
</tr>
<tr>
<td>Neurosurgical intervention for head injury</td>
<td>240</td>
</tr>
<tr>
<td>Advice to stop smoking from general practitioner</td>
<td>270</td>
</tr>
<tr>
<td>Neurosurgical intervention for subarachnoid hemorrhage</td>
<td>490</td>
</tr>
<tr>
<td>Antihypertensive treatment to prevent stroke (ages 45–64)</td>
<td>940</td>
</tr>
<tr>
<td>Pacemaker implantation</td>
<td>1,100</td>
</tr>
<tr>
<td>Valve replacement for aortic stenosis</td>
<td>1,140</td>
</tr>
<tr>
<td>Total hip arthroplasty</td>
<td>1,180</td>
</tr>
<tr>
<td>Cholesterol testing and treatment</td>
<td>1,480</td>
</tr>
<tr>
<td>Coronary artery bypass graft (left main vessel disease, severe angina)</td>
<td>2,090</td>
</tr>
<tr>
<td>Kidney transplant</td>
<td>4,710</td>
</tr>
<tr>
<td>Breast cancer screening</td>
<td>5,780</td>
</tr>
<tr>
<td>Heart transplantation</td>
<td>7,840</td>
</tr>
<tr>
<td>Cholesterol testing and treatment (incrementally) of all adults aged 25–39</td>
<td>14,150</td>
</tr>
<tr>
<td>Home hemodialysis</td>
<td>17,260</td>
</tr>
<tr>
<td>Coronary artery bypass graft (one vessel disease, moderate angina)</td>
<td>18,830</td>
</tr>
<tr>
<td>Continuous ambulatory peritoneal dialysis</td>
<td>19,870</td>
</tr>
<tr>
<td>Hospital hemodialysis</td>
<td>21,970</td>
</tr>
<tr>
<td>Erythropoietin treatment for anemia in dialysis patients (assuming 10% reduction in mortality)</td>
<td>54,380</td>
</tr>
<tr>
<td>Neurorsurgical intervention for malignant intracranial tumors</td>
<td>107,780</td>
</tr>
<tr>
<td>Erythropoietin treatment for anemia in dialysis patients (assuming no increase in survival)</td>
<td>126,290</td>
</tr>
</tbody>
</table>

*Reprinted with permission from Maynard [3].

Table 6. Comparison of Costs per Quality-Adjusted Life Year (QALY) of Competing Treatments*
associated with performing a well-designed economic analysis can be overwhelming. As a result of these factors, we strongly encourage orthopaedic surgeons to collaborate with healthcare economists and experts in public health when designing and performing economic evaluations.

In summary, although previous reports have shown that THA ranks high among common healthcare interventions in terms of cost per quality of life year gained (Table 6) [3], to verify and test the validity of this assumption, orthopaedic surgeons must begin to prospectively collect data regarding the costs and outcomes of THA. To help facilitate this goal, national total joint arthroplasty registries should begin to include economic variables in the databases. As increasing constraints continue to be placed on scarce healthcare resources, it is incumbent on orthopaedic surgeons to perform sound, evidence-based healthcare economic analyses to show the true value of THA to our patients and to society.

Appendix

Results of classification of 81 studies in the English orthopaedic literature containing “hip arthroplasty” “cost” or “economic” in the abstract or title. Studies are classified by study type subject perspective costs considered source of cost data time horizon use of discounting or sensitivity analysis techniques whether or not accepted methodologic criteria were met [5] the name of the journal in which the study was published.

References